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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. IX August, 1921 No. 2

Research in the Automotive Industry

By Dr. H. C. Dickinson[1]

THE Research Committee and the Council have much satisfaction in announcing that Dr. H. C. Dickinson, known to the members as a result of his conspicuous work at the National Bureau of Standards and in basically helpful cooperation with the automotive industry, will have immediate charge of the Research Department of the Society. Dr. Dickinson is relinquishing service with the Government in devotion to the purposes and tenets underlying the decision that the Society shall proceed in an organized way to further cooperation and coordination in research fundamentally requisite in the solution of the more immediate engineering problems confronting the members as a whole.

Nature, complex in gross, hides her secrets from untrained reason. Experiment, a sort of cross-questioning, separates out a particular group of facts, examines them alone and makes possible answers showing the rationality of things. Dr. Dickinson analyzes herewith in a preliminary statement the methods that are to be followed in and what can be expected from the momentous step being taken by the Society.

BEFORE discussing the subject of research, it is important to agree upon the meaning of the term. Research, as the term is used here, means merely a diligent search for information. Such information may come from the literature or from experiment and observation. Thus, research may be classed, for convenience, under three heads: (*a*) explorational, (*b*) intensive and (*c*) developmental.

Explorational research is usually preliminary in character. It deals with the fundamental analysis of problems through the study of available literature and of the technical and economic conditions involved. It serves to direct intensive research and development along desirable lines.

Intensive research includes the major part of the work usually accomplished in experimental research laboratories. It generally requires considerable laboratory equipment and the results should serve to supply the mass of detailed technical information necessary for industrial progress and development.

Developmental research cannot always be readily differentiated from the more common process of development by trial and error. The mere trial of one expedient after another in an attempt to solve a technical problem without an analysis of the requirements of the problem and of the causes of failure of the various expedients, can hardly be classed as research. This is the method of evolution, as well as that by which practically all the mechanical arts have received their initial development. It seldom leads to the highest efficiency and never to a knowledge of principles. Properly developmental research involves the application of experimental facts and principles to the solution of practical problems.

Need of Research

The automotive industry has attained its present position and magnitude through a development involving, among other things, a large measure of good fortune. An important factor has been the relatively easy and rapid interchange of ideas among members of the industry, together with the opportunity of giving practical expression to new ideas in the form of new models of vehicles. This has led to a rapid process of evolution in which the "survival of the fittest" has promptly elim-

[1] M.S.A.E.—Manager, research department, Society of Automotive Engineers, New York City.

inated those ideas that had not reached a practical commercial stage, rather than those that were unsound in principle. There is reason to believe that this evolutionary process can no longer go on at the same rate as in the past. It is an expensive process at best, and, perhaps responsible for some of the present depression in the industry. On the other hand, it would be a fatal mistake to retard progress in development, and more efficient means of progress are needed. Such means are to be found in a more general application of analytical methods in development. For instance, such problems as the overall cost of truck transportation, involving both the cost of vehicles and the cost of roads, cannot be solved correctly without a careful preliminary study of the various factors involved and of their relative importance as regards the general economics of the problem. The truck builder cannot safely design and market vehicles that will increase unduly the cost of roads, nor can the road engineer afford to design roads that limit unduly the hauling capacity.

In the matter of fuels, there are essential relations between the quality of fuels that can be produced and the design of engines that will use these fuels economically. The adaptation of one to the other has in the past lagged far behind the changing fuel-quality, with consequent fuel waste. There are also necessary relations between cost of the fuel, tires, repairs, and the like, and the number and weight of vehicles that can be maintained in service throughout the country. Changes in any of the items of cost demand changes in the design of the vehicles.

Explorational research should point the way in which progress should be directed. With this information at hand the designer will immediately require the best information as to how to modify designs in accordance with the probable future demand; in other words, apply the results of intensive research in development.

Opportunities of the Society

While the need of fundamental research is perhaps no greater in the automotive industry than elsewhere, the Society of Automotive Engineers is in the enviable position of being one of the youngest and largest of the engineering societies. Its membership is made up in great part of young men who are accustomed to cooperate in an industry in which change is the order of the day. There could hardly be a more favorable field for the organization of a systematic research program such as the Society has decided to undertake; nor has any other industry better facilities in men and equipment for the prosecution of such a program.

Research Facilities

Facilities for research include both personnel and material equipment. While the latter is much more readily classified and therefore constitutes the major exhibit in lists of available facilities, the former is by all means the more important factor from the point of view of research accomplishment. Research men, like artists, are born, not made, although their abilities must be developed through instruction and experience. This refers not so much to research-laboratory assistants, so to speak, who may be able to carry out the details of experiment or run tests, but rather to those men who must be looked to for all analytical thought and constructive ideas that research develops. Such men are rare and can do their best work only under favorable conditions. The success of any research depends primarily on the *interest* of the investigator. For this reason research men cannot be instructed as to what problems they shall undertake, except within very wide limits. The term "direction of research" is a misnomer. Research can be guided but hardly directed.

Research institutions may be divided into three general classes: (*a*) Industrial laboratories, connected with and supported by individual firms or corporations; (*b*) educational laboratories connected with colleges, universities and technical schools; and (*c*) independent research laboratories such as those of the Government and a few endowed institutions whose chief aim is research rather than instruction. Each of these three classes of laboratory has advantages and disadvantages, and each should be in a position to supplement the others in the development of any general research program.

The industrial laboratories are primarily supported directly or indirectly by the profits on the results they obtain. This being the case, they are usually subjected to insistent demands for the completion of any work in hand to a point that will permit its prompt commercialization. On the other hand, they have the advantage of the closest possible contact with the requirements of the industry in their particular line. While the demand for prompt results may make for increased productivity, it is almost fatal to the prosecution of comprehensive researches to a final satisfactory conclusion. These conditions are favorable to developmental research but distinctly unfavorable to explorational and intensive research, since even very important and valuable results are likely to fail of final verification or not reach the stage of publication for lack of time. Another handicap that should be removed from many industrial laboratories is that of secrecy. Since the results of development must often be held in confidence, this does not apply to fundamental facts that result from explorational and intensive research. A free interchange of such facts is absolutely essential to any constructive research development.

There are many industrial laboratories at the present time that have excellent material facilities and able men who are doing little that can be classed properly as research. They are purely development laboratories. The possibilities of these laboratories should be realized to much greater extent.

Educational Laboratories

The chief object of educational institutions is necessarily the instruction and training of students. This function cannot be neglected if the industries are to have trained technical men available. In most cases, therefore, the research laboratory must have for its prime object the training of men rather than the securing of results. Unfortunately, in most cases the professors who might carry on important independent researches, if time were available, are too fully occupied with their official duties as teachers to permit more than supervision of the work of students. In a meager number of cases research fellowships enable educational institutions to retain the services of a few men whose time can be devoted mainly or entirely to research; but in most cases these men expect to remain not more than a year or two. Only a limited class of research problems can be undertaken successfully by students, or temporary research fellows, viz., problems of such a nature that they can be completed in comparatively brief periods by men of relatively immature experience. In most cases the laboratories are not in as close contact with the requirements

of the industry as might be desired; the problems are necessarily selected more often for their suitability in the instruction of students than for their importance to the industry.

The chief needs of the educational laboratories seem to be a closer contact with the problems and requirements of the industries, such assistance as can be given in the way of securing the selection of problems of greater importance and a more general recognition on the part of our educational institutions that high-grade men with time to accomplish important researches on their own account can alone supply to the students that inspiration without which research training is almost useless.

Independent Laboratories

The independent laboratories are represented mainly by those of the Government. Their main financial support does not come directly from the commercialization of their results. Hence they are not hampered as are the commercial laboratories by demands for immediate results. When equipped with adequate facilities it is possible for these laboratories to undertake fundamental problems requiring more continuity of time and more equipment than are available in most educational laboratories, and problems of a more fundamental character than most industrial laboratories will undertake, because such problems are considered less fruitful in immediate commercial results. These laboratories have, however, the disadvantage of inadequate contact with the industries and may not appreciate the relative importance of their various problems. The independent laboratories cover a field not occupied by either of the other classes of institution.

Utilization of Existing Facilities

In theory the various laboratories and individual investigators should be occupied with the kinds of problem with which each is best fitted to deal. This would mean a minimum of duplication of effort and each man working at a suitable task. Unfortunately, this is an ideal utterly impossible of attainment, and a serious attempt to attain it would wreck any research program at the beginning.

Much has been said of late about duplication of effort in various lines, particularly in research. Although unnecessary duplication may be inexcusable in general, some duplication in research is both necessary and unavoidable and should be utilized, rather than prevented, but excessive and ill-considered duplication should of course be prevented. It is necessary because no fundamental research is or should be accepted at its face value until the results have been checked and rechecked by independent observers. It is unavoidable because research men do effective work only on problems in which they are vitally interested, and several are usually interested in the same problems. Moreover, the competitive element between different men and institutions when properly controlled is one of the greatest inducements to thorough and accurate work. This requires a free and adequate interchange of information between men and institutions. Such interchange of ideas can be depended upon largely to prevent unwise duplication and leave in the field only those most likely to succeed.

All men and institutions are, however, interested in lines of work which promise results of value, and the selection of the most promising lines of intensive research depends upon an adequate survey of the field, i. e., upon explorational research, the importance of which seems not to have been fully appreciated.

The aims of the Research Department of the Society for the immediate future are to encourage and secure so far as possible a more systematic survey of the research field as applied to our industry, to bring to the attention of the various laboratories such problems as appear in most pressing need of solution or of increased attention, and to secure to the greatest extent feasible a more general interchange of information between the various laboratories and individual investigators.

In attempting to develop such a system of interchange of information a sharp line of distinction is recognized between development or developmental research and fundamental or intensive research. The former must be considered of a private and confidential nature, while the latter is distinctly of more value if mutually shared by all members of the industry.

The Society bespeaks the hearty assistance and cooperation of all laboratories in securing a wider distribution of those results which are of general value to the automotive industry.

REINSTATEMENT OF 1919-1920 DELINQUENT MEMBERS

As announced in The Journal for July, the Council directed at its May meeting that the names of over 100 members should be stricken from the rolls of the Society for non-payment of dues for the fiscal year beginning Oct. 1, 1919.

Paragraph 16 of the By-Laws provides in part that a person dropped for non-payment of dues must, if desirous of again joining the Society, first pay the dues in arrears at the time of being dropped, and may then make a new application for membership, and further that the Council may in its discretion restore to membership any person whose membership has ceased for any cause, upon such terms and conditions as it may at the time deem best for the interest of the Society.

At the meeting of the Council held in June, applications for reinstatement were received from several of those who had ceased to be members of the Society by the action of the Council in May as stated above. In the case of those who in conformity with the provisions of the By-Laws mentioned above, sent remittances for the dues in arrears at the time they were dropped, the Council voted to grant reinstatement without the payment of an additional initiation fee, this action being taken in view of current industrial conditions. The instances in which the Council has waived payment of another initiation fee by those wishing to rejoin the Society are few in number and there have been no such cases until within the last few months when it was felt that unusual conditions required special action.

It being clear, however, that it is necessary that there be some time limit beyond which the Council will not grant reinstatement under the conditions set forth above, without payment of another initiation fee, a resolution was passed that Sept. 1 next should be set as a limiting date, with the direction that due notice to this effect be given in The Journal.

JUNE COUNCIL MEETING

THE meeting of the Council held on June 23 was attended by President Beecroft, Vice-Presidents Bachman and Crane, Councilor Pope, Treasurer Whittelsey, Chairman Scott of the Meetings Committee and Chairman Copland of the Transmission Division.

The Treasurer's report showed that the unexpended income of the Society for the first eight months of the current fiscal year was $6,377.16, the income for the period having been $165,940.21. The expense was $50,436.95 less than originally contemplated by the budget. The total assets of the Society on May 31 were $190,627.35, with accounts payable of $10,824.82.

Some interesting figures were presented with regard to the attendance at the Semi-Annual Meeting of the Society held at West Baden, Ind. in May. The total number present was 698, there being 114 ladies in the party and all of the men present except 52 being members of or applicants for membership in the Society. It is somewhat remarkable and also significant that there were more members at West Baden than at any previous Summer Meeting of the Society, with the exception of that held at Dayton in 1918 which was a meeting of rather abnormal size owing to war conditions, 649 members and 351 guests being in attendance. The attendance at the meetings held at Ottawa Beach in 1919 and 1920 totalled 634 and 816 respectively. There were 346 members present at the Ottawa Beach sessions in 1919, and 471 in 1920.

The applications for membership that were ready for consideration by the Council were submitted and 72 applications for individual membership and 2 for student enrollment approved. The following transfers were made in grade of membership: Associate to Member, J. A. Edwards, W. F. Barrett; Junior to Member, Z. C. Bradford, Milton Evans Chandler, Otto L. Formigle, Ford L. Prescott, Joseph Rawley, Samuel E. Rowe, J. A. Thompson, B. Russell Shaw; Member to Foreign Member, J. F. Engberg.

It was reported that 414 applications for membership had been received during the first five months of this calendar year, as compared with 578 during the same months of 1920.

The following appointments to the Standards Committee were made with assignment as indicated:

P. J. Dasey—Engine Division
George L. Bixby—Storage Battery Division and Electric Vehicle Division
George S. Cawthorne—Truck Division
R. C. Schell—Passenger Car Division
L. A. Chaminade—Passenger Car Division

Ralph Murphy was designated as Chairman of the Passenger Car Division.

In connection with the Sectional Committee of the American Engineering Standards Committee being formed to draft an aeronautical safety code, V. E. Clark, H. M. Crane, G. C. Loening, R. H. Upson and I. M. Uppercu were designated as representatives of the Society.

In connection with the plea made by Mr. Goldbeck of the Bureau of Public Roads at the meeting of the Society held in May that a committee consisting of highway engineers and automotive engineers be formed, it appears that the most important feature of such a program is a fuller appreciation of the general problem of the economics of transportation, involving a proper balance between the cost of construction and maintenance of highways and the cost of construction, maintenance and operation of vehicles. Engineers associated with the highway departments of various States have made a rather careful study of the problems of road construction and maintenance. From the point of view of the automotive engineer the problems of the users of trucks are obviously important, since the pivotal point involved is that of the general economics of transportation rather than the technical problems of the design and construction of motor trucks. It is believed that a careful survey of the whole general problem of costs of truck transportation should be made and a projected program for the next year or two be decided upon with a view to showing clearly the estimated relative importance of the various technical matters requiring investigation.

INSPECTION OF ABERDEEN PROVING GROUND

MILITARY preparedness consists not in maintaining a vast accumulation of costly military stores, munitions and fighting apparatus which in most cases become worthless through obsolescence; nor does it require the establishment of a considerable standing army of fighting men. It is vitally necessary, however, that each person shall know how he may be of most use to the country in war time. His usefulness will depend upon his understanding of military requirements and this ability to assist in the working out of such problems as may be encountered. The more knowledge he has of these matters before the outbreak of war, the less time will it take for him to get into action when the need arises.

Considering the importance of motor transportation in war, the automotive engineer has his field definitely laid out in advance. He must design, build, operate and repair the motorized equipment. To do these things intelligently he must be in close touch with the developments and experiments of the War Department.

Major-General C. C. Williams, chief of Ordnance, United States Army has extended an invitation to the members of the Society to visit Aberdeen Proving Ground, Maryland, on Friday, Oct. 7. Included in the invitation also are members of other engineering societies interested in ordnance developments. The Army Ordnance Association will, in addition, hold its annual convention at Aberdeen on the same day.

The Aberdeen Proving Ground is, in the opinion of ordnance experts, the most complete establishment of its kind in the world. Tests are made there not only of guns, ammunition and armor-plate, but also of aircraft and automotive equipment. During the war a complete plant for the manufacture of gas and the loading of gas shells was constructed and put into operation at Aberdeen.

The Pennsylvania, Metropolitan and Washington Sections will visit Aberdeen on Oct. 7 in lieu of their October meetings, and it is expected that the attendance will include many members from more distant points than the headquarters of these sections.

Aberdeen Proving Ground is located a short distance north of Baltimore, somewhat off the line of the Pennsylvania Railroad. Special Army trains are run, however, connecting the Proving Ground with the Aberdeen railroad station.

Full particulars regarding train schedules and a detailed program of the exhibits to be scheduled and tests to be made will be given later.

Fundamental Points of Carbureter Action

By F. C. Mock[1]

BUFFALO SECTION PAPER *Illustrated with* DRAWINGS AND CHARTS

IT is always difficult to determine exactly, and define accurately, the actions that enter into the functioning of a carbureter because these are so intimately interconnected with many others equally complex and equally vital, all uniting in the operation of the modern internal-combustion engine. In carbureter work one must hold fast to an absolute faith in physical science and the immutability of Nature's laws; many things seem to happen that we can reject, at the time, only because we know they cannot be and yet we must be always alert to find the errors of our previous conceptions and ready to accept the existence of forces and phenomena that were not known before. We must steer a mean course between the attitude of the unskilled service man, who believes that the carbureter, if properly built, can compensate for all deficiencies in the 600-lb. mass of metal beside it under the hood, and that of the theorist, who would plan it all out on paper without soiling his hands in experimental tests.

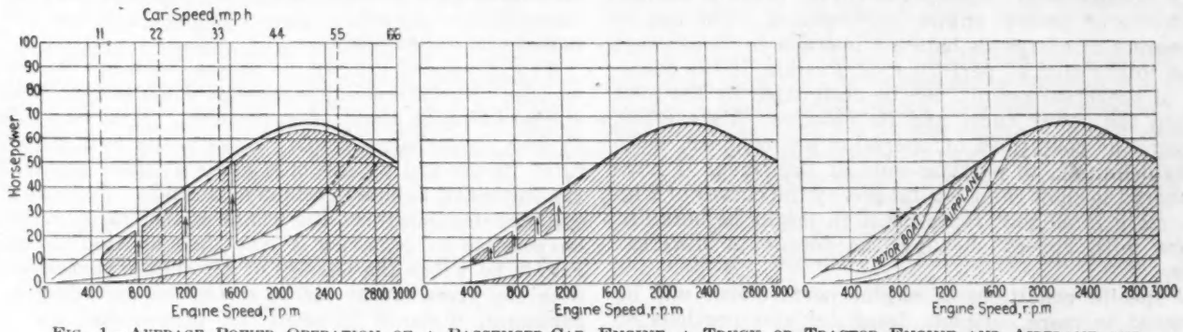


FIG. 1—AVERAGE POWER OPERATION OF A PASSENGER-CAR ENGINE, A TRUCK OR TRACTOR ENGINE AND AIRPLANE AND MOTORBOAT ENGINES

As the subject of carbureter action is broad, it seemed possible in such a paper as this only to select and set forth some of the main laws and basic considerations that apparently exist and which we use as guides in the engineering work of our own organization. I believe that an understanding of these laws will be of great assistance to all automotive engineers, particularly those engaged in engine and motor-car development.

CARBURETER VERSUS FUEL INJECTION

Before proceeding further with the subject I want to justify the effort thus involved by making a brief defense of the carbureter as a means of supplying fuel to an engine, particularly as compared with the fuel-injection method. In the modern carbureter, which if my memory is correct has been cruelly characterized by a fuel-injection advocate as an "uncertain and complicated device suitable only for laboratory use," rotation of the engine draws in the air, the inflow of air draws its charge of gasoline in a fixed proportion and the engine cannot rotate without getting its predetermined mixture proportion. Further, the mixture is *stable* under changes of load and speed, a point that we appreciate only after trying other methods of fuel feed; for instance, a gravity, needle controlled, flow of gasoline into the mouth of an upturned intake-pipe.

In the carbureter the fuel is fed as a steady stream through a metering orifice and the effect of surface tension becomes negligible. For fuel injection each charge must be an individual minute drop or globule. Under the range of temperatures encountered the change in metering due to change of capillarity and viscosity will be very high and as soon as the walls of the injection duct get hot the globule, with the range of fuel volatility we have to handle today, will tend to disintegrate due to the boiling of its light elements.

Furthermore, the present motor-car fuel system operates on a range of quantity of mixture, from light load low speed to high speed full load, of over 30 to 1, and goes smoothly and positively from any one point in the range to any other. The very essence of the usefulness of the motor car and motor truck lies in this flexibility, in traffic service, under adverse road conditions and the like. The tractor and the airplane were satisfactory at first with a limited speed-range and little flexibility, but as they have developed much greater flexibility has been demanded. Is there a small high-speed multi-cylinder fuel-injection engine in existence today that has a speed and load range of 3 to 1 and will make the change smoothly and without danger of stalling?

With the modern type of carbureter there is very little trouble due to wear, deterioration or change of the instrument in service. We know now that most of the difficulties formerly charged up to the carbureter were due to the non-volatility of the fuel and could be overcome only by changes in other parts than the carbureter.

The fuel situation has been steadily changing in the last 7 years. In each engine-building department of our large factories the value of the production equipment is hundreds of thousands of dollars. Is it not sane economics to do as much as possible in adaptation to the

[1] M. S. A. E.—Research engineer, Stromberg Motor Devices Co., Chicago.

changing fuel situation with a small easily modified device such as the carbureter, rather than worry along under continuous and uncertain, but always costly, modifications in engine design? If we can make the car operate better by introducing new elements into the carbureter and these elements are positive and permanent in their operation, is there any reason whatsoever why this should not be done? In fact, there are some carbureters in use today whose construction is not complicated enough. If the characteristic of a given type of carbureter is such, for instance, as to give an unduly rich mixture in certain parts of the average driving range, or if some other equally important defect is present, we can say, I think, that the design of this carbureter is not complete until these faults have been remedied.

Conditions in Cylinder, Manifold and Carbureter During Normal Operation

The first thing necessary in a consideration of this subject is a clear and definite understanding of the conditions existing in the carbureter and the intake-manifold. As every carbureter man knows to his sorrow, the ordinary dynamometer "horsepower curve" is not at all representative of general engine performance. The engine can operate at all speeds between idle and full load; that is, the total range of performance possible, if the conditions of operation permit, can be designated by the area between the power curve and its baseline. Very often, however, the conditions of operation are confined, more or less definitely, to portions only of this area. I have endeavored to show these limitations by the curves of Fig. 1. A more intelligent representation might be obtained perhaps with curves showing the torque at different speeds.

The specific conditions of engine performance will be considered in more complete detail in later portions of this paper relating to mixture requirements. It is sufficient to point out here that for passenger cars the full power of the engine is seldom used at ordinary speeds, but is used very often at low engine speeds because only small throttle-openings will give full torque at this time. As we all know, the full power of the engine at high speeds is used very seldom indeed. The motor truck and the tractor have considerably less range of action than the passenger-car engines, while motorboat and airplane engines, working under propeller load, are very definitely limited as to range of torque and speed.

We all understand how at wide-open throttle the rate of mixture delivery from the carbureter depends upon the engine speed and the volumetric efficiency. At part throttle and part load, however, these relations are less clear, the quantity of mixture passed being governed partly by the throttle position and partly by the engine speed. It is very important that we understand the conditions existing in the intake-manifold of these different throttle positions, loads and speeds, as well as under changes from one condition to another.

Relation of Throttle Position, Manifold Vacuum and Engine Torque

The throttle, I might point out, is not necessarily a part of the carbureter, although usually so considered. There are some who think of the throttle as controlling the volume of air fed to the cylinders; instead, the volume of charge per cylinder is constant and the power of the engine is regulated by the change of the mixture density in this fixed and continuous volume of cylinder charge. Now, if we select any engine speed and vary the throttle position under changing load with the correct mixture proportion, we find that the charge density in the manifold, as shown by barometer readings, bears a definite relation to the torque developed; also that this relation is almost identical for all engine speeds. Fig. 2 contains a set of curves illustrating this, and Fig. 3 gives a general average of the results of our record tests. We believe that the curving over of the lines of Fig. 2 is an indication of the intake-valve restriction and that it is possible to determine the valve limitations by this method of analysis.

The maximum torque is usually obtained at not over 1½ in. of vacuum. This cannot be given as an exact figure because the vacuum registered is partially due to air velocity and partially to kinetic energy losses, and for other reasons, but 1½ in. is a fair average for all speeds with engines of four or more cylinders on one manifold. One of the reasons for not securing an air charge at atmospheric density, or 100 per cent volumetric efficiency, is the expansion of the air charge when it enters the hot combustion-chamber. It is obvious that under such conditions a slight initial rarefaction of the air charge, as expressed by this 1½ in. of mercury vacuum will have little or no effect upon the charge density at the end of the intake stroke.

The developed torque decreases with an increasing vacuum or a decreasing barometer down to zero with the engine idling at about 18-in. vacuum. It is very difficult to find what charge density corresponds with zero indicated torque and we can only guess at these points, with the volume of exhaust residue as a guide. For any given cylinder temperature and compression ratio it should be possible to construct a line such as that dotted on Fig. 3, by which the density of air charge corresponding with any given torque can be estimated, according to the horizontal distance between the torque and zero consumption line. The space at the left of the zero consumption line represents the volume of exhaust residue in the cylinder at the beginning of the intake stroke.

The left portion of Fig. 4 shows the gain of torque with decreasing speed, for a given size of air-opening. The line *a* indicates the torque that would be obtained with a throttle-opening which would give a 16-in. vacuum at 1000 r.p.m. This is about the torque required to drive the average car on a not too smooth country road. If the road becomes rougher or a hill is encountered so that the speed of the engine is reduced to 800 r.p.m., this will decrease the air velocity through the throttle orifice, which will in turn reduce the manifold vacuum with an increase of about one-third in the torque as shown. A further increase of the load will slow down the engine and raise the torque still more, until, with this same throttle-opening, a full air-charge will be delivered to the engine, and full torque developed at about 130 r.p.m.

A similar condition exists with regard to the resistance of the entire carbureter at wide-open throttle and high speed. The lines *b* and *c* at the right of Fig. 4 show a comparison of the power developed by two carbureters, one of which, *b*, has 2 in. of mercury vacuum at 2400 r.p.m., and the other, *c*, considerably smaller, 4 in. The dotted line is a rough approximation of the power required to drive a 3400-lb. touring car, at road speeds in the relation of 22 m.p.h. to 1000 r.p.m. of the engine. It will be noticed that the difference between the carbureters *b* and *c* is insignificant at 2000 and disappears entirely at 1800 r.p.m. This is the reason carbureters of widely differing air-capacity may show so little difference in steady pulling torque at ordinary driving speeds.

Nearly every engineer remembers that sometime in his experience he expected to get a tremendous gain in power from a car by using a larger carbureter, and how very slight a gain, if any, was shown. Occasional instances have been reported in which the larger carbureters, and vacuum of less than 1 in. of mercury, gave better torque than carbureters more nearly the customary size, but I think that in each case careful investigation would have shown that the gain was due to something else than an increased delivery of the air charge.

Effect of Manifold Vacuum Upon Vaporization

As we have seen, decreasing the manifold vacuum tends in general to increase the torque, but another opposite effect is possible, due to changes in the rate of evaporation. Uniform mixture quality requires that the fuel-vapor density maintain a fixed proportion with the air-charge density. Also, we know that with the fuels used today the vapor density obtainable at ordinary atmospheric temperatures and pressures is much less than necessary to furnish a combustible mixture with air. Giving concrete estimates, at 80 deg. fahr. the vapor density of our average gasoline might average only about 1/45 of that of air, in which case, if you feed from the carbureter a fuel-to-air mixture of 1 to 15, only one-third of the fuel could and would vaporize. If, without change of mixture temperature, we close the throttle and

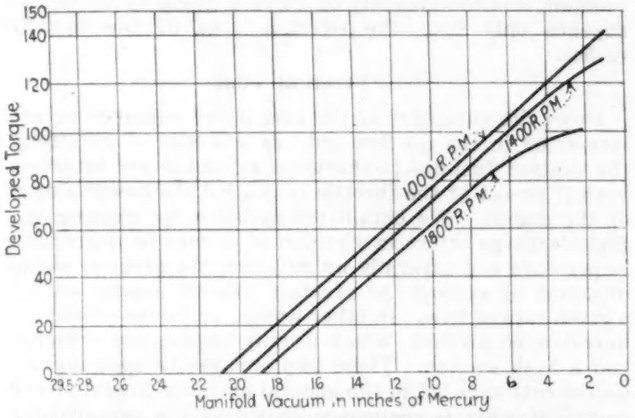


Fig. 2—Curves Showing the Relation between the Vacuum and the Torque Developed by an Engine

cut down the density of the air in the manifold to one-third that of the outside atmosphere, a fuel-air ratio from the carbureter of 15 to 1 in this reduced charge will give a vapor density of 1/45 that of atmosphere and under such a condition the manifold will be substantially dry. This results from the fact that for average temperatures and grades of fuel there is a torque limit below which the mixture will be substantially dry. Further throttle-opening may not increase the torque in proportion to the increased air-charge because of incomplete vaporization, a condition that can be remedied somewhat by enriching the mixture so as to get a greater vapor-density from the light elements of the fuel. Stated in another way, for every change of temperature, below a certain critical point, there may be a change in the mixture proportion needed for maximum power.

Another effect of this manifold vacuum condition, less evident in a theoretical consideration of the subject than in actual experimental work, is the invitation to air leakage into the intake system. This tendency to leakage is the highest when the weight of air-charge per cylinder is least, so that a very small leak at the exhaust-valves,

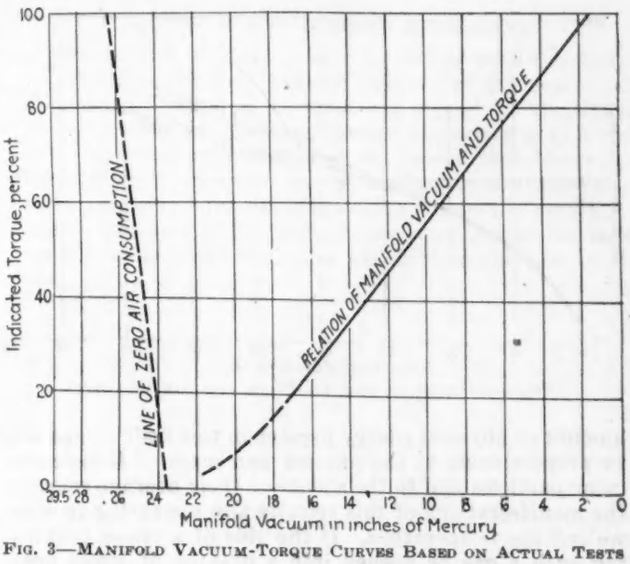

Indicated Torque, per cent
LINE OF ZERO AIR CONSUMPTION
RELATION OF MANIFOLD VACUUM AND TORQUE
Manifold Vacuum in Inches of Mercury

Fig. 3—Manifold Vacuum-Torque Curves Based on Actual Tests

valve-guides or manifold joints may seriously disturb the operation of the engine under light loads, but show no effect on full-load pulling.

This relation of vacuum and torque explains the failure of the multitude of "economizing" devices put on the market in recent years, which consisted of suction valves designed to be mounted on the intake manifold, opening inwardly under the vacuum. Their opening was greatest when the throttle-opening and the air delivery of the carbureter were least, and in no possible way could they be made to exert anything like a uniform corrective effect upon the mixture at different engine speeds.

Air-Flow

A study of the air-flow in carbureters presents continuous difficulty because this flow, while in reality following known physical laws, is often deceptively disturbed by factors whose presence is not evident. As it is difficult for many to understand how air-flow in the carbureter can generate "suction," it may be best to begin our consideration of this subject with an analysis of the conditions of energy existing in the airstream.

According to our present conception of matter, a gas under pressure is made up of molecular particles in rapid motion, individually irregular as to direction and velocity, their average impact against the retaining walls developing what we observe as the gas pressure. The

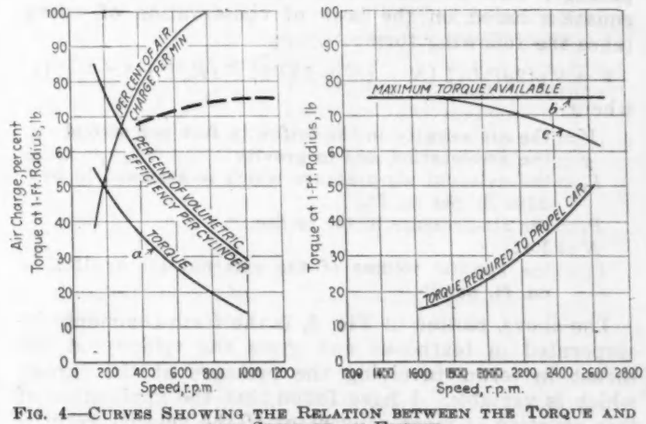


Fig. 4—Curves Showing the Relation between the Torque and the Speed of an Engine

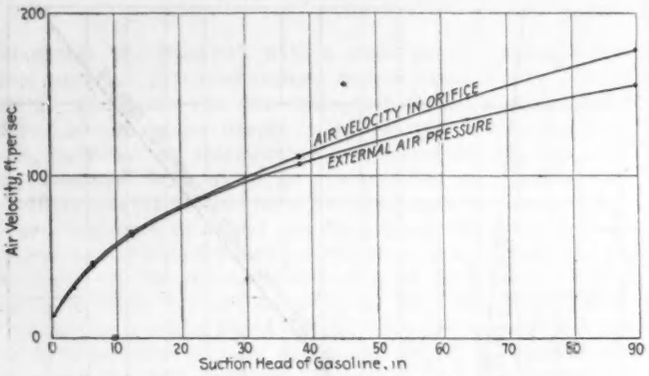


FIG. 5—CURVES OF THE AIR-FLOW AND AIR VELOCITY

amount of physical energy present in this body of gas will be proportionate to the number and mass of these molecular particles and to the square of their average velocity, the manifestations of this velocity also appearing in what we call the temperature. If the side of a vessel containing such a gas be opened into a passage of lower pressure, the gas particles will issue forth, but without any addition or subtraction of energy. The total amount of energy present in their motion must be the same as before, so that if this stream of particles has a definite direction, instead of being balanced in all directions as before, whatever velocity is gained in this one direction of flow, means a reduction in the relative molecular velocities normal and opposite thereto. That is, when a fluid enters upon a condition of flow, there is a corresponding reduction in its pressure. If we can get this conception of air at rest consisting of molecules in motion in all directions at a tremendous velocity, and of the air as it flows through the carbureter to the intake-manifold having this molecular velocity slightly increased in the direction of flow to the engine and correspondingly decreased in other directions, we will then be able to understand many of the apparent anomalies which our experimental determinations seem to disclose.

Much of our experimental uncertainty arises from the difficulty of measuring average pressures in the air-stream. In a carbureter or intake-manifold the stream is nearly always turbulent and non-uniform; also nearly any sort of pressure-measuring tube is likely to generate eddies around its measuring orifice, so that the greatest care is necessary for any reliable determination of the air-pressure distribution. If we consider the action of air-flow past a resistance concentrated at one point of the passage, such as the venturi tube in a carbureter, an equation based on the laws of conservation of energy takes the following form:

$$V = \sqrt{([2gP_1U_1]\ [N \div (N-1)]\ [1-(P_2/P_1)^{(N-1)/N}])}$$

where

V = the air velocity in the orifice in feet per second
g = the acceleration due to gravity
P_1 = the external air-pressure which is assumed to be 2102 lb. per sq. ft.
P_2 = the air-pressure in the orifice
N = 1.41
U_1 = the specific volume of the external air or 13.13 cu. ft. per lb.

The above, plotted in Fig. 5, is the form commonly incorporated in textbooks and gives the velocity at the throat in terms involving the pressure at the throat, which is variable. I have found that the application of this equation is more convenient if the velocity term is modified to give, instead of the actual velocity, the velocity that would exist if the density were the same at the restriction as in the air entering the carbureter. With such a velocity term it is possible to compute much more readily the weight of gas flowing under known areas and venturi throat pressures.

$$V_d = \sqrt{([2gP_1U_1]\ [N \div (N-1)]\ [(P_2/P_1)^{2/N} - (P_2P_1)^{(N+1)/N}]}$$

The notation in this equation is the same as in the previous one except that

V_d = the velocity at the initial density or external air-pressure P_1 that would give the same weight of flow as the velocity V at the pressure P_2

These values also are plotted in Fig. 5. In both curves the rate of air-flow in feet per second is given in terms of the corresponding reduction of pressure in inches of head of gasoline of 0.75 specific gravity.

As is shown by an inspection of these equations, a peculiar condition arises when the air discharges into a vacuum or pressure of less than half the original absolute pressure. In general, the rate of flow increases with the drop of final pressure, but at a certain point, about 14½-in. vacuum, a limiting velocity is reached, which is, by the way, the velocity of sound. This has a bearing upon the flow of air past small throttle-openings. At all vacuums above 14½ in. of mercury the velocity of flow is constant and the quantity of air-flow going to the engine depends only upon the effective area of the throttle orifice.

THE VENTURI TUBE

From the viewpoint of the carbureter engineer we are interested in the air-flow only as a means of obtaining the desired fuel-flow; otherwise we would not interfere with it except at the throttle to control the power output of the engine. We obtain the fuel-flow by locating the fuel-discharge orifice in a region of suction or depression in pressure and naturally we will have the greatest range of action by getting the greatest possible depression for a given rate of flow. In other words, we desire equally an unrestricted air-flow, which usually implies low velocity, and a high suction. These two apparently opposing requirements have led to the general adoption in carbureter design of what is commonly known as the venturi-tube form of air passage, shown at the left of Fig. 6. The action of the molecular forces in passing through this shape of channel is obvious upon consideration. The rounding or converging entrance gives a free air supply right up to the point of greatest contraction. Upon passing this the components of pressure against the expanding taper

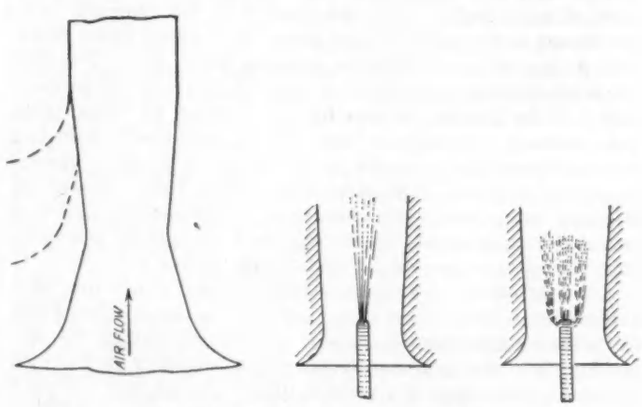


FIG. 6—TYPES OF CARBURETER JETS

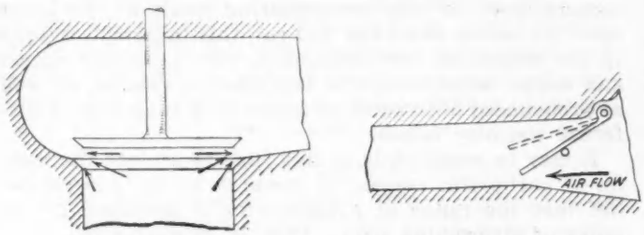


FIG. 7—WEIGHTED AND HINGED TYPES OF AIR-VALVE

of the walls yield an onward reaction that permits a rise of pressure. This rise or recovery of pressure at the outlet is what distinguishes the venturi-tube action from that of a bushing or choke.

One thing I do not understand, and for which I have never seen an explanation, is the fact that there is a definite limit upon the taper of the discharge part of the venturi tube; above 7 deg. on a side the action seems to decrease markedly, regardless of the velocity or, so far as we have measured, of the density of the medium. At smaller angles than this the efficiency falls off slightly, to an extent that might be due to the wall friction. The angle of entrance seemed to be of minor importance provided there is a smooth transition at the throat to the diverging contour. One point in venturi-tube design which is seldom emphasized is that the outer or collecting part of the entrance should be definitely larger in area

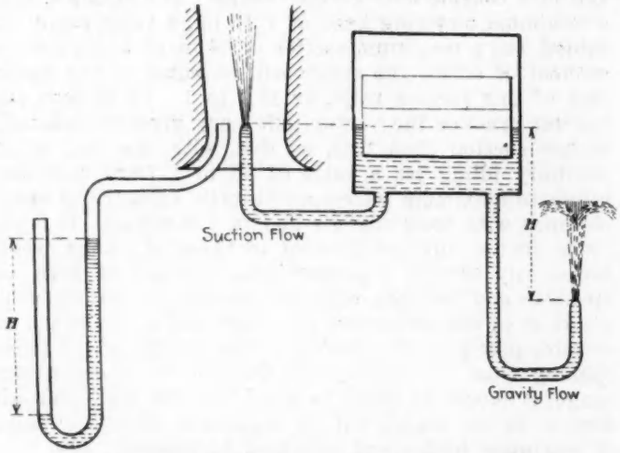


FIG. 8—SUCTION AND GRAVITY FORMS OF FUEL FLOW

than the outlet, in the same way that it is necessary to obtain a high coefficient of discharge for a given size of plain orifice. The dotted line at the left of Fig. 6 may show more plainly what I mean.

Another thing not generally understood is that the flow of gasoline in a venturi tube greatly disturbs its action, the derangement increasing with the rate at which gasoline is fed and the extent to which it is atomized. Some of the loss in energy of air-flow is occasioned in accelerating the gasoline from the jet, as shown in the views in the center and at the right of Fig. 6. In the former, which is the jet with the side outlets, the fuel is shown by its parabolic line of travel, which we have often observed, to accelerate to the speed of the air in a very short distance of travel; this generates a fine atomization, but considerable resistance to air flow. A jet such as that at the right does not exercise so great a restriction on the air-flow, but the fuel is not so finely broken up nor will the spray spread as widely in the same shape of passage as with the one shown in the center.

FLOW OF AIR THROUGH AIR-VALVES

The general conditions vary so widely with the design of carbureter that no general analysis of the flow of air through air-valves is possible. It should be mentioned, however, that very few carbureter air-valves give a constant pressure-regulation for the reason that there is a diminution of pressure on the surface of the valve near the approach to the opening orifice where the velocity is high. The area of this reduced-pressure section increases with the valve-opening. For instance, in the case of the

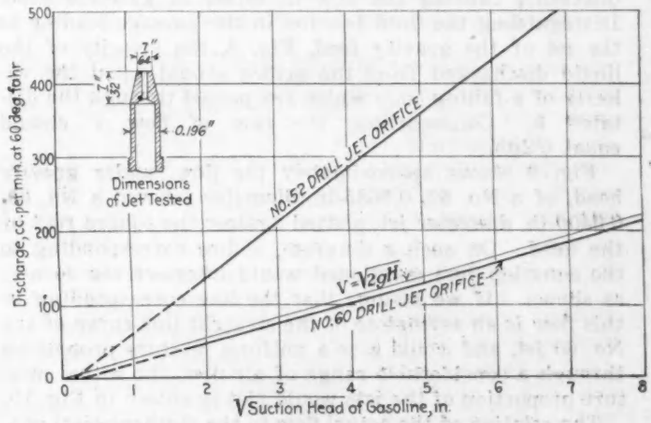


FIG. 9—CURVES OF FUEL FLOW THROUGH TWO CARBURETER JETS PLOTTED AGAINST THE SUCTION HEAD

weighted air-valve at the left of Fig. 7, if the area of the valve were 4 in. and the weight 2 lb., the valve would begin to open at a suction of ½ lb. per sq. in. and maintain this pressure above it for the first small opening. By the time the crack of opening became appreciable there would be a diminution of pressure around the circumference of the valve near the crack, so that the vacuum above it might perhaps reach ⅝ lb. As the opening increased, this action would increase still further. Therefore a valve of this type cannot be depended upon to give anything like a constant vacuum in the carbureter.

This action is still more marked in a hinged type of valve inclined slantwise across the air-opening. I have experimented with a valve such as that shown in Fig. 7 at the right and found that, with no spring at all, if I held it wide-open, it would suck to the position shown by the dotted line at a high engine speed. It will be noticed that the valve constitutes in effect a nozzle-shaped entrance and the fall of pressure within it is very similar

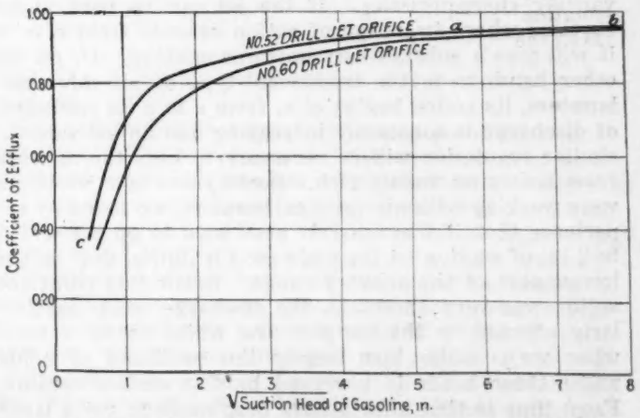


FIG. 10—THE ACTUAL MIXTURE PROPORTIONS OF THE TWO JETS WHOSE FUEL FLOW IS GIVEN IN FIG. 9

to that in the entrance to the venturi tube shown at the left of Fig. 6.

Fuel-Flow

The rate of liquid flow through an orifice of fixed size is customarily and most conveniently gaged according to the pressure causing the flow. This pressure may be that of gravity as shown in Fig. 8, or a difference of pressure measured in terms of the gravity head. In either case, under an equality of forces, the rate of flow should be the same. In our work we usually refer to the pressure difference causing the flow in terms of gasoline head. Disregarding the fluid friction in the passage leading to the jet of the gravity feed, Fig. 8, the velocity of the liquid discharged from the orifice should equal the velocity of a falling body which has passed through the distance h. Consequently, the rate of flow V should equal $\sqrt{2gh}$.

Fig. 9 shows approximately the flow, under gravity head, of a No. 52, 0.0635-in. diameter jet and a No. 60, 0.0400-in. diameter jet, plotted against the square root of the head. On such a diagram, a flow corresponding to the equation just mentioned would intersect the corner, as shown. If we assume that the line corresponding to this flow is an asymptote of the straight line curve of the No. 60 jet, and would give a uniform mixture proportion through a considerable range of air-flow, the actual mixture proportion of the jets would plot as shown in Fig. 10.

The relation of the actual flow to the mathematical one, which we may call the coefficient of efflux, is in my opinion due mainly to surface tension, for the following reasons:

(1) At times when this coefficient is low the fuel can be seen very definitely clinging to the tip of the jet
(2) Submerging the jet and providing means for drawing off the fuel as fast as it is supplied to a normal level, without imposing any additional suction on the jet, will give very close to a uniform ratio of flow to the square root of the head
(3) Introduction of air near the outlet of a submerged jet, with sufficient definite bubbling within and a splashing discharge from the jet will give a quantity to give a substantially straight-line mixture curve

It has been suggested that the height of the jet above the level is responsible for this deficiency. This height is to a certain extent responsible, but inspection of curves similar to those of Fig. 9 shows that the jet would need to be about $\frac{3}{8}$ in. below the level to give an approximately straight line.

It will be noticed that the flow from a plain jet has varying characteristics. If the jet can be used under suctions where its range of action extends from a to b, it will give a substantially uniform mixture. If, on the other hand, as in the traditional type of air-valve carbureters, its action begins at c, from c to a its coefficient of discharge is constantly increasing and an air-valve or similar regulation will be necessary to keep the mixture from becoming unduly rich. Some years ago, when we were working with air-valve carbureters, we found by experience that it was scarcely ever wise to go below $1\frac{1}{2}$ to 2 in. of suction on the plain jet for idling, that is, the lowest part of the delivery range. Below this point the action was very uncertain, the discharge being particularly affected by the temperature, which seems natural when we consider how largely the coefficient of efflux under these heads is governed by the surface tension. From time to time efforts have been made to get a large high-to-low speed range performance from a plain jet by coming down to very low metering heads at the lower end. As nearly as we can find out, this invariably results in the difficulties just mentioned, very uncertain action and undue sensitiveness to temperature change, as well as pronounced differences of action with fuels having different viscosity values.

It may be worthwhile at this time to analyze the matter of carbureter range. It seems to be the general belief that the range of a carbureter is governed by its range of air-opening sizes. This, is, of course, one limitation, but the size and capacity of the fuel orifice is equally responsible. As a sample computation, the No. 60 plain jet above described, at a minimum operating suction head of $1\frac{1}{2}$ in. will pass 23 cc. of gasoline per min. If we assume that the limiting manifold depression at high speed is 2 in. of mercury and that the efficiency of the venturi system employed in the carbureter is such that a 2-in. manifold depression gives 4 in. of mercury depression on the jet or 64 in. of gasoline head, the flow from the jet at this time would be 214 cc. per min., a ratio from high to low speed of 9.3 to 1. A greater range than this from such a jet can be obtained only by increasing the efficiency of the venturi by increasing the manifold vacuum, or by going lower on the low end of the metering curve.

A jet structure whose coefficient of efflux is free from the retarding influence of surface tension and gravity will meter down to very much lower heads, with the result of a considerably greater range. For example, with a minimum metering head of 7/16 in., a value easily obtained, and a maximum suction of 64 in. at a constant coefficient of efflux, the range will be equal to the square root of this suction ratio, or 12.1 to 1. In modern carbureter practice the venturi efficiency gives considerably higher suction than this, so that with the help of an auxiliary idling jet a ratio of 50 to 1 from minimum idling to maximum wide-open throttle capacity is easily obtained with fixed size air and fuel openings. It is obvious that a further marked increase of range would necessarily involve a proportional increase of both air openings and fuel jets, with considerable mechanical complication of the carbureter structure and a loss of the inevitable precision of metering characteristic of the fixed-opening type. In dealing with the question of carbureter range, it should be borne in mind that the maximum air demand of the engine will be reached at about the point of maximum high-speed indicated horsepower; also that the air capacity of a carbureter system is not a definite amount but increases considerably with a slight increase in the manifold vacuum.

There are a few miscellaneous points, which may be of interest, concerning the behavior of the fuel in the air column in the carbureter. The most noticeable characteristic of the gasoline, under observation of glass models, is the extent to which its action is governed by the surface tension. It clings to every surface it touches and would always much rather run along the surface than fly off. Very many jets that have been proposed as having fine spraying and atomizing qualities prove exactly the opposite, on account of this clinging effect. The fuel spray tends always to seek out and deposit at the points of low velocity. One of the most difficult things in developing a carbureter of very high speed-range is the problem of keeping the spray in suspension. To vary the fuel and the air openings in proportion is much less difficult than to ensure the gasoline rising steadily from the small low-speed air opening up to the throttle and the intake-manifold through the large body space necessary

for the full air opening. The tendency of the fuel to gather and load in this space is always very pronounced. In fact, much of the difficulty ascribed to lack of compensation in the jet delivery is really a failure to get the fuel from the jet to the throttle.

Mixture-Proportion Reqirements

Since practically all of our automotive applications of power have a reserve capacity, that is, their full power range is in excess of their normal operating power, it follows that the mixture-proportion requirements can to some extent be gaged as dependent upon the position of the throttle. At partially closed throttle maximum power is not a consideration, and a mixture of maximum economy is desirable. At wide-open throttle, however, the maximum-power mixture is desired in nearly every case, provided this can be obtained without too much sacrifice in fuel consumption. The records of the Society contain many experiments to determine the exact mixture proportion required to give these two characteristics, maximum power and economical fuel consumption and, as might be expected, the values obtained vary with every engine tested. It is obvious, first, that the fuel supply must be increased whenever there is any unequal distribution of the fuel, as the weakest cylinder must be supplied. Low fuel consumption, therefore, requires either a partial vaporization or fogging of the mixture, or else a high air velocity in the manifold along with the proper contour. Since the vaporization is so much more complete at closed than at open throttle, our distribution troubles and the manifold contour are important almost only at wide-open throttle and for this reason, with the average motor-car engine, we can run on a thinner mixture at part throttle, or above about 12-in. manifold vacuum, than at wide-open throttle. That is, the mixture of maximum power at part throttle is nearly always leaner than the mixture of maximum power at full throttle. Under circumstances where the fuel evaporates completely in the intake-manifold, the leanness of mixture that can be used is limited by the ability to ignite and propagate combustion, for which conditions are more favorable at the full compression of a wide-open throttle than at the lower compression of part throttle, with also a higher percentage of exhaust dilution.

We do not find any reliable evidence that an increase in the fineness of atomization beyond a certain point, reached in nearly all carbureters, will give any effect upon power or fuel consumption, provided the discharge from the jet is steady and not intermittent. It seems that vaporization reaches its limit at 100 per cent atomization. It is, of course, worthwhile to keep the spray off the manifold walls so far as possible.

In illustration of the foregoing, Fig. 11, is a typical mixture-proportion curve. The wide-open throttle setting, being that of maximum power, will usually be uniform for intermediate and high speeds but somewhat richer at low speeds, both because of poorer manifold conditions at this time and because detonation is less likely to occur with such a mixture. The closed-throttle range may be leaner than that at wide-open throttle at ordinary driving speeds and such a setting will give exceedingly smooth operation when the engine is in good condition. When the valves begin to leak, a richer mixture may be needed to cover up partly the irregularity of firing charge. At idling the very thin air-charge, the high percentage of exhaust residue and the uncertain leakage of air through the valve-guides make a very rich mixture necessary. The exact mixture-proportion required under each of these conditions will depend, as can readily be understood, upon the individual characteristics of the engine and the fuel used. Also, they vary quite definitely with the service for which the engine is used. An effort will be made to analyze these requirements under the different divisions of passenger cars, motor trucks, tractors, motorboats, airplanes, racing cars and dynamometer tests.

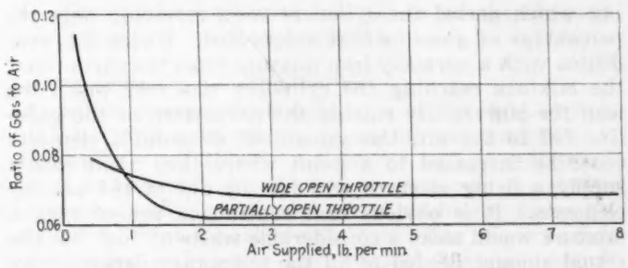


Fig. 11—A Typical Mixture-Proportion Curve

Passenger-Car Mixture Requirements

For passenger-car service the predominant requirement to-day is ability to accelerate from closed to open throttle at the moderate or legal range of speeds. Practically all carbureter adjustments are made to give this acceleration, most drivers gage the ability of their car by its response to the throttle, and a large part of our factory demonstration work on the road is directed toward the attainment of this important point. This is natural and proper because the full power of the engine in present-day driving is nearly always used to give a gain in speed, except in a few hilly localities, and many times when it is called upon, the safety of the driver depends upon its response. At present, country roads and city streets alike are so generally crowded that the time made on either a long or short trip depends more upon the ability of the car to thread its way through traffic, to slow down and pick up quickly, than upon the maximum speed. This matter of acceleration is so important that nearly any carbureter will receive favor, regardless of faults in other details, provided it fulfills the function of giving prompt and positive acceleration.

So far as the action in the carbureter is concerned, acceleration requires, first, a mixture-proportion and condition of vaporization that will pull full power at wide-open throttle and low speeds. I might comment on the fact that while it is customary nowadays to take power curves from 3500 to 800 r.p.m., it is very seldom that the dynamometer horsepower curves are carried down much lower. But just as soon as we make a carbureter test on the road we try to get acceleration from something like 1 m.p.h., which means full power from 60 r.p.m. up.

We further find that in addition to a powerful steady running condition, acceleration is greatly improved by a temporary excess of gasoline. The need of this excess feed was very clearly explained by the recent experiments of the Bureau of Standards with glass intake-manifolds. It was found that at wide-open throttle, with ordinary fuels and the ordinary range of temperature available, a large part of the gasoline travels from the carbureter to the cylinder along the manifold walls at a rate of speed relatively much lower than the air speed. At closed throttle so much greater a percentage of the fuel evaporated that almost none was on the walls. Now, in throwing the throttle open from the closed position, the wall-flow took a considerable time to become established, dur-

ing which period the cylinders were receiving only the percentage of gasoline that evaporated. Under this condition, with a normally lean mixture from the carbureter, the mixture reaching the cylinders was very much too lean for power. By raising the proportion of the gasoline fed to the air, the amount of evaporable elements could be increased to a point where they alone would supply a firing mixture without the aid of the heavier elements. It is obvious that continuous use of such a mixture would mean a considerable waste of fuel, but the actual amount needed to fill the temporary deficiency on acceleration is small. We find from experiments that a thin steady running mixture, with means for temporarily enriching the mixture as necessary for acceleration, will give better acceleration than a carbureter without such an accelerating device, set so rich that the engine lopes in driving along the street at closed throttle. It is rather remarkable that the application of different means of heating the walls of the manifold does not do away with the need of this accelerating extra fuel supply, although it cuts down the amount required. In comparison, the use of hot air on the carbureter comes nearer giving acceleration on a normal mixture. Visible observation shows that when such conditions are attained the fuel evaporates almost entirely within a few inches from the jet and that there is much less wall-flow. According to the analysis just given, the extra charge on acceleration should be delivered at the moment of the change from high to low manifold-vacuum, and we find in practice that this is the case. This requirement cannot be fulfilled with precision by accelerating means dependent upon the throttle opening nor upon an increase of the carbureter suction, since neither of these coordinates invariably with the fall of the manifold-vacuum; on the other hand, some precautions are necessary to prevent the large accelerating charge that is necessary for some engines from all going into one or two cylinder ports. However, too much is far less objectionable than too little and there are a number of satisfactory accelerating devices in use which do not conform entirely to the above statement of requirements.

Fuel Economy.—We all try to obtain low fuel-consumption as a characteristic of passenger-car operation. Since the average speed of a car in most sections of the country lies between 10 and 35 m.p.h. and at closed throttle, the normal driving range indicated in Fig. 1 should be set for best economy, although in practice drivers will not use such a mixture setting unless it is possible at the same time to get good acceleration.

There are two factors, really wholly outside the scope of this paper, that have much to do with the fuel consumption. The first is the mechanical efficiency of the engine. With the average 3500-lb. car having a 4½ to 1 gear-ratio about 5 hp. is required to drive the car at a speed of 20 m.p.h., about 1¾ hp. to overcome the loss of pumping against the manifold-vacuum on the intake stroke and about 3½ hp. to overcome the friction of the engine, a mechanical efficiency of 48 per cent. As many cars are delivered with their engines very stiff, for the first 2000 miles the mechanical efficiency is less than 35 per cent. With, for instance, a 2¼ to 1 gear-ratio in a four-speed gearbox, the pumping loss would be about 1 hp. and the engine friction about 1¾ hp., so that at the same power output the mechanical efficiency would be about 65 per cent. If the 4½ to 1 gear-ratio gave 16 miles per gal., the 2¼ to 1 ratio should give 22. A trial of a well designed four-speed gearbox with a flowmeter indicating the fuel consumption, will show what a tremendous effect this factor exerts. An average value of the torque required to propel a car at moderate speeds on smooth level roads is 50 lb. per ton of car weight. At a fuel consumption of 0.65 lb. per hp-hr. a 3500-lb. car would travel 41 miles per gal. and a 2000-lb. small car, 72 miles. The difference between these figures and what we actually do make is due less to deficiencies in our engine cycle than to the fact that we operate at so low a percentage of the normal engine torque. A fuel-injection engine would probably be even less efficient under these same conditions, on account of the extra power required for driving the various auxiliaries not found on our present type of engine.

Another factor that we find in our service stations raises the passenger-car fuel consumption is the tendency of the average driver to retard the spark to prevent the engine from knocking at wide-open throttle, and leave it that way for steady driving at closed throttle. That is very common with cars having high-compression engines and poor manifold systems which invite the accumulation of carbon in the combustion-chambers. For ordinary legal-speed driving at from 14 to 16-in. manifold-vacuum, the spark should be advanced almost to the point necessary for maximum car speed.

Hill-climbing at ordinary speeds is largely a question of proper mixture proportion and favorable conditions of vaporization. The capacity of the carbureter does not enter much into this because nearly all carbureters, as has been brought out, are adequate in size for the speeds at which hills are climbed. At low manifold velocities and wide-open throttle with the present heavy fuels there is an accumulation in the manifold that increases rapidly and if it goes into the cylinders in occasional slugs will give the action known as "loading." It is not generally appreciated, but a hill test can be made a very delicate demonstration of the nature of the torque curve of a car, particularly with engines whose torque drops off at low speeds. Referring to the dotted-line curve at the left of Fig. 4, if the inclination of the hill is such that it just equals the torque of the engine at this speed, any slight increase that could be made in the torque would increase the engine speed to a region of increased torque whereby the engine would accelerate and continue to gain speed, provided the inclination of the hill were constant. On the other hand, the merest diminution in torque, even a single miss-fire in one cylinder, would cause the engine speed to drop slightly to a region of decreased torque, under which the car would start to lose speed still further and it would probably be necessary to shift gears within 60 ft. In the hill testing that I have witnessed, particularly before proper methods of manifold heating came into vogue, this point was a source of very great waste of time and much useless work. The skill of the driver and the natural variations of manifold temperature made big differences in the hill performance and all engaged in the test used to rack their imagination to find explanations for the different results we seemed to find.

Speed, in the average driver's estimation, is what we might characterize more definitely as good acceleration up to 45 m.p.h. Such determinations as we have been able to make show that the power required for high speeds crosses the curve of engine torque at such an angle that considerable variations of torque at the very high end make only small changes in car speed and such apparently small factors as wind direction and wheel-traction road-surface make very considerable differences. For long stretches and speedway work speed is simply a question of having enough air and the right amount of

fuel to go with any type of carbureter which I know of that is positive in its operation. Our service experience indicates maximum car speed is to the average car owner the least important of all requirements; not even 1 per cent of our complaints are directed to this point. It is not so much that the drivers do not think they want speed as that they do not use it often enough to know whether they have it, and it takes a very considerable loss in engine power to make a change in maximum speed that the average driver can detect.

A carbureter for any service should, in my opinion, be reasonably simple and positive in operation. It should be possible for production carbureters to be made alike and so that after any reasonable overhauling any one can be restored easily to its original condition. The carbureter should be as wearproof and dustproof as possible, so that it will not deteriorate or change adjustment during the life of the car. This is rather difficult to insure with carbureters of the variable gasoline orifice or metering-needle type. In every case this type of carbureter should have a dashpot piston to keep the attendant air-valve from hammering and wearing the seat of the metering-needle seat. It is advantageous to have the idling mixture adjustable separately from the remainder of the mixture range, because slight manifold leakages, valve-stem leakages and the like affect this proportionately much more than other parts of the mixture range. The action of the carbureter should be unaffected by the jolting of rough roads.

Motor Trucks

The range of operation of motor trucks is such that the engine works through a lesser range of speeds than in the case of passenger cars, and the manifolds are usually designed so that this speed range corresponds with the higher range of manifold-velocities, with the result that carbureting conditions are much easier. Also, four-cylinder engines are as a rule easier to handle than those of larger numbers of cylinders, due mainly to conditions of manifold distribution. These advantages are offset, however, by the practice, which is extensive in motor-truck construction, of dropping the carbureter very low down to get gravity fuel-feed from a gasoline tank under the seat. This necessitates a long manifold, and very few trucks indeed are equipped for proper heating of the fuel charge after it leaves the carbureter, with the result that the fuel condenses in the manifold and the difficulties of acceleration are considerable. The governor valve and its chamber also act as intercepting and loading points for the fuel spray. I believe that experience will show that the life of the engine in a motor truck can be very greatly prolonged by proper design of the intake-manifold and correct selection of the carbureter and that this consideration, even more than that of fuel consumption, will soon lead to the use of more effective provisions for vaporization on motor-truck engines.

Tractors

The duty of a carbureter in tractor work is considered easy because the load is supposedly steady. Actually, however, there are periods in service when flexibility is needed badly. With kerosene as fuel it is possible with high manifold-velocities and by use of a carbureter having good atomizing properties and a charge well diffused through the airstream, to perform pretty well with a low mixture-temperature, provided the cylinder jackets are fairly warm. Even so, we can scarcely say that successful general operation on kerosene has been attained as yet. The tractor carbureter should be of the simplest construction and entirely dustproof.

Motorboats

As will be noted from the diagram at the right of Fig. 1, the range of performance of an engine attached to a propeller falls within very definite limits, also the condition of unfavorable evaporation at wide-open throttle is encountered only under the correspondingly favorable condition of high manifold-velocities. The requirements of motorboat carburetion are, therefore, the simplest of any automotive branch. Due to this condition, however, only recently has there been any pressure upon the designers to provide for adequate heating of the intake-manifold, and very many engines are in use today whose performance suffers on this account. Nearly all the later designs show that these considerations are now being given attention.

Airplane Carburetion

In airplane service the propeller load and the fact that relatively highly volatile fuels are used make the engine typical of this field the easiest on which to demonstrate carbureter performance on the dynamometer test stand. But in the air there are a number of special requirements which render the airplane field perhaps the most difficult of all the branches of carbureter work. First, the mixture tends to grow richer with increase of altitude, in the proportion of the square root of the change in the air density. Second, it is desirable that the carbureter should function properly in every position that the airplane may assume. Third, the carbureters are usually more or less subject to the deranging influence of the propeller blast, which sometimes almost equals in magnitude the velocity of the air past the metering jets of the carbureter. It is nearly always possible to compensate for this by balancing the float-chamber of the carbureter on the air entrance. Fourth, the high mechanical efficiency of airplane engines and the fact that a number of carbureter units are usually employed on one engine, make it very difficult to obtain a satisfactory idle and low-speed range, and, on this account, positive and certain acceleration. When we add to these points the requirements that the carbureter should give at all times the smoothest possible firing of the engine, that effective precautions must be taken against any stoppage of the jets or mechanical failure and that every effort should be exerted to prevent backfires, it is evident that much work is necessary before a perfect airplane carbureter can be produced.

Carbureter and Engine Tests

In our demonstration work throughout the country we encounter widely different methods of engine testing to determine carbureter merit, some good and some, in my estimation, not so good. In view of the importance of this work it seems worthwhile to set forth, for discussion at least, what seem to be the essentials for obtaining accurate and trustworthy information.

Dynamometer tests should obviously reproduce conditions of actual operation, not only as to the temperature of cooling water, the air around the engine, and the air entering the carbureter, but also as to speeds and loads. The full power-range of a passenger-car engine should be brought down to the speed demanded in road operation, while the fuel consumption should be taken at loads corresponding to normal driving. Most important of all, in my estimation, the power should be plotted as torque against speed. The method in general use at present of

plotting the horsepower, which is the torque times the speed, against the speed, results in a form of curve in which undue prominence is given to a relatively unimportant and rarely used part of engine operation. When one looks at such a power curve the eye instinctively goes to the peak and gives this consideration to the exclusion of everything else. Yet nearly every car makes its maximum road speed at a higher number of engine revolutions than that of the peak of the power curve, so that it is the power beyond the peak that determines the maximum car speed. Also the horsepower-speed curve is very unsatisfactory as a means of indicating low-speed pulling ability, or as a basis for fuel-consumption tests at part load. In fact, it does not at all depict the power performance or ability of a car, except possibly for advertising purposes.

Since the power of the engine at full air-charge is dependent upon the density of the air entering the carbureter, this should be recorded, and corrections made for temperature and barometer in all tests of maximum torque. Care should be taken to have the air supply clean and not contaminated by the exhaust. If the intake-manifold is near the exhaust-manifold, at high speed and full load the radiation from the latter may heat the intake unduly and cause the power to fall off.

For fuel-consumption tests the friction horsepower of the engine should always be recorded and comparisons made upon the basis of indicated horsepower. This is particularly important with part-load tests.

Since present-day requirements are such that the carbureter adjustment used in service is determined by the ability to accelerate, it would be of great value to have a dynamometer equipped with a flywheel disc to give an inertia equivalent to that of the finished car. A disc of this sort is in use at the Bureau of Standards.[2]

There should by all means be in plain view a thermometer giving the intake-manifold temperature, without which intelligent comparisons cannot be made. It is advisable also to have a gage reading the intake-manifold vacuum, as this, along with the temperature, governs the rate of vaporization and the extent to which the mixture delivered by the carbureter will approximate that received by the cylinders. A flowmeter is very useful to give a general indication of the fuel consumption under different conditions of driving.

An easily read accelerometer is of great value. It not only gives an idea of the power developed but can also be used to read the road and wind resistance, from the rate of deceleration with the clutch out, thus removing two otherwise unknown variables in a fuel-consumption test.

It is believed that the foregoing covers the main points to be considered in the development of proper carbureter action. It will be noticed that this work falls definitely into two distinct parts; the first, a joint responsibility of the engine designer and the carbureter engineer, being to determine the specific mixture and vaporization requirements of an engine; and the second, for which the carbureter engineer alone is responsible, to produce an instrument that will deliver reliably and consistently such a fuel-charge with as favorable vaporization conditions as can be obtained. Successful results can be obtained only by close and cordial cooperation. I am glad to say that in the past few years this cooperation has been general and that our work has been more efficient and much more pleasant on this account.

[2] See THE JOURNAL, August, 1920, p. 131.

THE INTERNAL-COMBUSTION TURBINE

THE largest internal-combustion turbine yet constructed appears to be that due to Mr. Holzwarth, who published in 1911 some very meagre details of a turbine, designed by him to develop 1000 hp., and which, at the outset at any rate, only yielded 150 hp. It was later on claimed that by modifications and improvements this figure had been raised to 450 hp., but the report was not one to inspire confidence. Reports are now to hand as to another Holzwarth turbine built by Messrs. Thyssen, which is claimed to have developed 984 hp., with an overall thermal efficiency of 26 per cent. It is claimed that the waste heat supplies all the energy required to operate the steam turbine compressor that compresses the charge to 33 lb. per sq. in. absolute before ignition. In view of Holzwarth's original paper and claims, this report must be received with some caution. The general method of operation embodies no novelty. The charge is compressed into an explosion-chamber and fired, expanding through a nozzle onto the buckets of a turbine wheel. As the pressure in the chamber falls the velocity of efflux diminishes, a condition that must involve somewhat serious losses in both the nozzle and the buckets. Moreover, the apparatus is necessarily complicated by the installation of a steam turbine compressing plant.

An overall efficiency of 26 per cent means an expenditure of nearly 10,000 B.t.u. per hp-hr. Such a figure is probably not beyond the reach of the steam turbine, and some interesting figures may be expected when certain extra high-pressure plants now in course of completion undergo their tests. The limit of steam turbine efficiency is certainly not yet attained, at least so far as the reaction type is concerned. As yet the steam-reaction turbine has not attained as high an efficiency as the corresponding water-operated turbine, but there is no obvious reason for this. In view of the foregoing there seems little likelihood that any form of internal-combustion turbine, of which particulars are yet available, will prove a commercial success. All obvious lines of development have in fact been fairly thoroughly explored, with disappointing results, a condition of things that tends to convey the impression that the difficulties are inherent in the system and not in its details.

In addition to the difficulty of devising a cycle that shall be at once efficient and mechanically simple, there are certain to be grave troubles from the rapid wasting of nozzles and buckets under the flow of white-hot gases. Hitherto experimenters have fallen back on carborundum for the nozzles, but this material is obviously unsuitable for the buckets. Could the massive tungsten used for the metallic-filament lamps be obtained in bulk at a sufficiently low cost, the bucket problem might be solved, since this metal has a strength comparable with tool steel, combined with a melting-point of nearly 3000 deg. cent. (5432 deg. fahr.)—*Engineering* (London).

PRECISION IN MANUFACTURE

IT was well proved in the war, and it is patent to any manufacturer operating upon a large production scale, that millions of dollars are lost through wastage because mechanical pieces vary a few millionths of an inch in measurement. The host of small-scale inspectors, filers, fitters and sorters who do not belong to the technical inspection or engineering staffs are paid wages because other workers make mistakes in work.—F. W. Hersey in *Michigan Manufacutrer.*

Automobile Locking-Device Classification and Theft Insurance

By A. R. SMALL[1]

METROPOLITAN AND CLEVELAND SECTIONS PAPER[2]

ONE certain way of eliminating insurance losses caused by the theft of automobiles is for the companies to refuse to write this form of coverage, and many underwriters would feel much relieved if this solution were generally adopted. Others say that this identical solution will obtain automatically when and if the premiums charged are further increased. But it is the business of insurance to reimburse a property owner for loss and it is the proper ambition of the modern insurance company to offer 100 per cent service or protection. Accordingly, we must presume that insurance protection against the theft of automobiles will continue to be furnished and we can consider ways and means of restricting the losses to an extent which will permit the protection that insurance affords to be provided at a non-prohibitive cost.

In the early years of the automobile the theft problem did not exist. Automobile-theft insurance, when and if written, was included by the agent and his company for but a nominal increase over the premium charged for fire insurance, merely to make the coverage complete. Persons who could drive cars were few. The appearance of a new or strange car in a community was a matter of neighborly comment; its history was known or readily ascertained. Without a closer analysis of the development, volume production and general utility became features in the definition of the automobile-theft problem. Statistics show at least 9,000,000 automobiles of the private passenger-car type licensed for use in the continental United States. It is probably a conservative estimate that there are three persons to every car now in use or from 20,000,000 to 25,000,000 persons who are provided with the knowledge for automobile operation.

Insurance losses from the theft of automobiles first reached serious amounts perhaps in 1913 and certainly by 1915. Most of the losses of that period did not involve theft for illegal sale and money gain but were from damage to the car resulting from unauthorized joy-riding. The general impression among automobile underwriters is that this cause of loss is not now a predominating factor of the total loss. Shortly after this the losses from drive-away disappearances caused disturbance, but this source of loss has largely vanished because of the comparative readiness with which railroads now furnish box cars for shipment. Whenever organized theft of automobiles upon a commercial scale had its beginning, its successful growth had become plainly manifest in 1917. From 1918 to 1920 inclusive, in part because of the universal list-price increases, when the used-car value became enhanced nearly 100 per cent of its original value as a new job and when decreased production due to war conditions delayed deliveries of new cars, the theft loss-ratio was shockingly large.

The so-called moral hazard is a factor in every general risk for which insurance is written. Its share of the gross loss ratio is not capable of analysis further than to observe that it varies with the economic situation of the people as a whole and with the public sensibility of general right and wrong. Normalcy, toward which all are working, should place this element in the background. There are those who assert that the use of stolen automobiles in holdups, bank robberies, liquor running and smuggling is merely a phase of this moral hazard, reflecting the extent to which the present moral sense of the general public is abnormal, but it is sufficient to record that such uses have made a new market for the stolen car and added perhaps to the list of active thieves.

The automobile-theft problem from the insurance viewpoint includes in its defining lines the following: (*a*) the automobile has become a utility, (*b*) which is generally available and (*c*) readily operated by the general public (*d*) without general comment; (*e*) the automobile readily lends itself to illegitimate use by the irresponsible joy-rider, (*f*) to organized theft for profit in the sale of stolen cars and (*g*) to vicious purposes to which the use of stolen automobiles is secondary. If this be the problem, it appears that features (*a*) to (*d*) will continue to grow with the industry. A job which does not have a general-utility value will not be a "commercial" proposition from the thief's viewpoint. As production schedules increase, more cars become available to the thief. A design that is not operable readily by the general public will have a limited legitimate distribution and likewise a restricted stolen-car sale-value. Only special bodies or freak jobs attract attention now. Accordingly, preventive or protective measures against the insurance losses from the theft of automobiles must take the direction of retarding their availability for illegitimate uses, and not combat the items that reflect the growth and prosperity of the automobile industry.

THEFT RETARDANTS

It is pertinent to emphasize the use of the word "retard," in contrast with "prevent" or "protect." The property of mobility being a primary essential of the automobile, prevention of theft while mobility persists is not possible, generally speaking. This has been recognized by Underwriters' Laboratories by the classifying of automobile locking devices as "theft retardants." It is believed futile to proceed on the theory that prevention is practical. In studying the sources of automobile thefts a clear distinction becomes evident immediately as to the efficiency necessarily demanded of retardants protecting against (*e*) and (*f*) or (*g*). That such a distinction exists between (*f*) and (*g*) is not so clear; in fact, it may not exist within the bounds of practical procedure.

The first locking device was the simple ignition-switch or plug having for its primary purpose a means for stopping the engine. This did not long suffice to prevent unauthorized use. Ignition-switches equipped with tumbler locks were the next development. Subsequently a

[1] A.S.A.E.—Vice-President, Underwriters' Laboratories, Inc., Chicago.

[2] The portion of the paper relating to locking-device classification was presented in New York City and that on other forms of automobile insurance, in Cleveland; the two were afterward combined for publication, although that was not the original intention of the author.]

more general knowledge of the wiring systems used on various makes of car has decreased materially the protection afforded by this type. Since 1915 various other locking means or methods have been developed. More than 100 makes, patterns or styles available as accessories are now classified by Underwriters' Laboratories, and some 15 to 20 are being furnished regularly as stock equipment by automobile builders. The several methods of locking comprised in this group are

(1) Ignition circuit locked open
(2) Gasoline feed line locked closed
(3) Intake-manifold locked closed
(4) Exhaust line locked closed
(5) Shifting gear locked in neutral
(6) Shifting gear otherwise locked
(7) Clutch pedal locked in depressed position
(8) Steering-wheel locked in the free position
(9) Steering-wheel locked in a fixed position
(10) Chains, clamps, bolts or other fixtures securing a wheel to the car frame, a lamp-post or a telephone pole

In at least 90 per cent of these devices a cylinder lock with a key of the pattern commonly known as the Yale is used. On one well-known high-priced stock car locks were provided on the ignition-switch, spare-tire holder, toolbox, hood clamps and at other points. These several locks on each car were operated by a common key and there were but 10 key-changes in the series; so access was necessary to only 10 cars to secure wax impressions for making a set of keys with which any car of this make could be stolen. The Detroit police once exhibited two complete sets of 50 keys each that had been taken from a thief. These covered the entire output of two popular makes of car. In view of such conditions the present requirement of Underwriters' Laboratories for at least 200 key-changes will not seem severe. Hardware stores and locksmiths sell blanks for various patterns of so-called Yale keys; hence our regulations call for keys with milled slots, duplicates for which cannot be secured in this ready manner. To prevent picking, tumbler locks must have not less than three pins and, to avoid forcing, key-slots should be flush in the cylinder face. Locking cylinders must be mounted properly to prevent ready removal and set-screws must have riveted heads if used for this purpose. In a similar way the operations and mechanical details must be studied and limitations set up to avoid the easiest ways of installation and of removal, but the theft of cars cannot be prevented. An extreme method reported as having been employed several times by a gang of organized thieves is that wanted cars were spotted and the habits of the drivers learned. When a car was left alone, a furniture van would be drawn up, a ramp would be lowered and the car hauled by a winch into the van. With the car inside the closed van would disappear. There is a practical limit to what can be demanded of locking devices. Given time, tools and freedom from apprehension, any locking device practical for use can be defeated. Some damage to car fixtures may result, but never to the extent of eliminating the profit to a thief.

It is believed that where the idea of money gain is not present, the regular use of a locking device of a type listed by Underwriters' Laboratories is effective in preventing the theft of cars for joy-riding; and that the regular use of such locking device is more than 50 per cent effective in causing commercial stealing to be confined to cars not so equipped. The use of standard locking devices is likewise not less than 50 per cent effective in defeating thefts when attempts against cars so equipped are actually made. Considering the number of stolen cars which are not equipped with modern standard locks and others stolen while left unlocked by the owner, an actual "fielding average" of 80 per cent or better is claimed for the present listed types and patterns.

Volume of Automobile Theft Insurance

Detailed statistics as to underwriting experience or volume in automobile-theft insurance are not available. The following figures are deduced from data given in automobile editions of several insurance publications. Approximately 350 insurance companies write automobile-theft insurance. Because of the limitations placed upon insurance practices by State laws and restrictions, this insurance is never written except as a side line of automobile fire insurance. In 1920 these companies assumed a theft liability of several billion dollars for an estimated premium of about $60,000,000. The figures show what is called an underwriting loss for the business, from which a computation can be made showing a distribution of this $60,000,000 premium-income as given in Table 1.

TABLE 1—DISTRIBUTION OF PREMIUM INCOME

Items of Cost	Percentage of Revenue	Amount
Sales Expense	25	$15,000,000
Overhead and General Operating, including reserve requirements	20	12,000,000
Detection and Adjusting Cost	5	3,000,000
Taxes	4	2,400,000
Payments on Claims	55	33,000,000
	109	$65,400,000
Net Loss	9	5,400,000

It is purely coincidentally that by a similar course of reasoning I conclude that of the 9,000,000 automobiles registered for 1920 not more than 5,400,000 are covered by any form of insurance protection, showing an average underwriting loss of $1 per car. But when we consider that companies writing only public-liability insurance, without the theft coverage included, take at least 40 per cent of the total automobile premiums collected, the estimate shows not only an average underwriting loss on the theft business alone of about $2 per car but, in addition, cash actually paid out for claims of at least $10 per car insured against theft. This indicates an assumed number of cars insured against theft of approximately 3,000,000, with an average premium of $20 per year and an average face value of $1,000 per policy, or an average rate of 2 per cent after all deductions.

But what is the significance of these admittedly questionable figures in explaining the underwriting loss, which has been referred to as averaging $2 per car for theft alone? The rate allowance, not including the penalty, for a labeled locking-device policy-warranty of 15 per cent produces for an average car a reduction of $3.50 per year. This amount is sufficient to take care of the underwriting loss with a margin sufficient to show a profit in the business. Assuming five years as the insurance life of the average automobile, it will be seen that the companies buy these locks at an average price of $17.50 each. It is known that not more than 1,000,000 labeled locks are in use and that at least one-half of these are on 500,000 of the 6,000,000 automobiles which are not insured for theft. Accordingly, the views of the executives of the insurance companies as to the value of this form of theft retardant seem to harmonize with those of 500,000 automobile owners.

At various times attempts have been made by our en-

gineers to classify or grade automobile locks as to their relative efficiency. So far such classifications are of sentimental rather than practical significance. The insurance companies differentiate the "accessory" and the "built-in" types and offer a practical consideration of 5 per cent additional credit for the latter. This is not especially to recognize superior merit in the locking devices or methods, but to acknowledge the value of avoiding defective or faulty installation and of selecting a type suitable for the problem presented by the special features of the design of a particular make of automobile. Further, it is felt that standard locks on the entire output of an individual maker is of practical benefit in the situation.

Our engineering staff is preparing a new set of requirements for the performance of automobile locks. Presumably, when finally adopted, these will constitute a composite of the present standards. But it is certain that such protection against theft is adequate only for a day or two, if that long, for the reason that there is no standard thief. Accordingly, education must be resorted to for whatever fraction of the total risk remains when the estimated efficiency of locks, watchmen and all other retardants is considered.

Other Forms of Automobile Insurance

Having discussed the methods of classifying locking devices to retard the theft of automobiles, let us consider other ways and to what extent insurance applies to the automobile and to problems of its design. The insurance companies are required to report various statistics with regard to losses and other items of the business but, because it is comparatively new, the statistics with regard to automobile insurance are not required in the same detail as for fire insurance, and it is difficult to establish the real extent of automobile contact with the insurance business.

The five common forms of insurance for automobiles are those of fire, theft, collision, property-damage and public liability. We already have considered the theft problem at length. Public-liability and property-damage insurance have much in common and features of design bearing on them will be considered ahead of the items bearing on the fire and collision hazards.

About 430 different organizations sell automobile insurance of one form or another, and something like 70 of these sell only liability, property-damage and collision insurance. These 70 organizations collect about $70,000,000 in premiums; the remainder collect $113,000,000 for fire, theft and collision, so that the statistics show the total premiums collected for insurance to be approximately $183,000,000 for 1920, or about $20 per car. The State license taxes on car owners amounted to $91,000,000, or about one-half the insurance premiums paid, and the insurance companies paid back to the car owners $93,000,000 on losses. Taxes paid by the insurance business to cities, States and the Federal Government represent about 5½ per cent of their income. It is estimated that in 1920 the insurance companies as a whole broke even on liability, property-damage, collision, theft and fire insurance, although certain branches did not do so and it had to average up. All of the companies writing collision insurance in the metropolitan sections undoubtedly lost money, although the insurance was sold at what seemed to be prohibitive rates.

Relation of Design to Insurance

Assuming a car that the public demands, very little, if anything, can be done from the viewpoint of automobile design to prevent the accidents which are covered by the liability policies. When driving at night in Chicago I sometimes think that if I had a different windshield I could see better. I have a sedan car with a blind spot when turning a corner. I do not know whether others have had the sensation of turning a left-hand corner and finding that they were pivoting on a car they did not see. Possibly the question of blind spots, from the driver's viewpoint, and whether to use a straight or a slanting windshield are items that designers should take into consideration.

One would assume that the first thing a designer should do is to put good brakes on a car, but I know of owners who are obliged to turn the front wheel against the curb to hold the car on a hill. It ought to be possible to design a brake that will not freeze and that will hold the weight of the car on a hill. One firm thinks that a brake-lining should have a coefficient of friction of 0.40 and another company thinks that a 0.14 friction coefficient ought to be good enough. If an engineer designs car brakes for 0.40 and the purchasing agent orders a brake-lining having 0.14 friction coefficient, will the latter be as effective when it is installed?

The question of liability-insurance cost depends largely upon the ideas of the public or a jury as to whether a car owner is to blame because he is rich and whether the insurance company should pay because it is rich. It depends also upon whether the public considers automobile driving as a speed performance and never stops, never looks and never listens. The driver has the greatest control over the liability cost. Formerly a verdict of more than $5,000 for death was unusual in the settlement of liability cases. Probably as a result of the Government's guarantee to the overseas forces of $10,000 in the war-risk insurance, a verdict of $10,000 to $20,000 for the death of a single person is not at all uncommon today. This is an added cost in public-liability insurance and likewise an added reason for purchasing insurance.

Property-damage is very much the same as liability insurance except that the latter has to do with injury to persons. If one runs into a store window or another man's car, and one cannot fix the blame on the other person, then one is liable and the property-damage covers the liability. What one has to pay depends upon the ideas of the courts and juries. Usually the policy is for $1,000, but I would recommend to some car drivers that their property-damage policy be increased; the jury may think one can pay a larger amount and award it. There is much comfort in $1,000; it will pay for many lamp-posts, but when one hits a high-priced car, one wishes that his property-damage policy were larger. For the $1,000 the insurance company will try the suit. The car driver has perhaps more influence on the losses paid by the insurance company for property-damage than any effort of the designer.

Schedule Method for Automobile Fire-Insurance Classification

Prior to the adoption of the schedule method by the National Automobile Underwriters' Conference for 1920 business, automobiles were classified for insurance purposes according to the list prices established by the automobile builders for their products. These list prices were divided into groups or classes arbitrarily, and rates or premiums were quoted for each such group or class varying inversely, although not proportionally, with the average list price in each class. During recent years automobile builders, like most other manufacturers, found

it necessary to increase prices. Not infrequently these price increases have been sufficient to transfer a line from one list-price classification to the next higher. In the case of one popular automobile the list-price changes from 1917 to 1920 resulted in advancing its classification according to the list-price method by two steps, although no material modification in the chassis or engine design or in its acceptability from the point of view of any form of insurance coverage had been made. These changes resulted in a rate decrease of 46 per cent. Assuming policies written on new cars for the respective full list-price values in each case, the combined fire and theft premium decreased $8.65; the liability increased $1,340, while no material consideration accrued to the insuring company. There is now in process a reversal of this situation which will result in list-price decreases with revised list-price classifications and increased rates for lessened liability and no material change in hazard. That the automobile owner and those serving him were complacent as regards the insurance cost with the automatic lowering of rates from list-price increases is by no means a guarantee of similar broad and smiling satisfaction with the shoe on the other foot.

The fire risk in automobile coverage may be resolved into three principal components. These are the exposure hazard, with the garage risk as its chief item; the moral hazard; and the hazard of design, assembly and equipment of the automobile itself. Of these three components the moral hazard is not measurable by schedule and because of mobility the exposure hazard can be specifically analyzed, if at all, only in the rough. These components, either severally or collectively, must be averaged and be reflected in a basic or key rate, modified by flat increases or decreases for territorial, economic or other conditions as experience or expediency may dictate. Observe that the automobile builder may not control in any measurable degree, through list price or through construction items, the loss ratio established by his line from these exposure and moral components of the risk. Deferring for later consideration the remaining component of the fire risk, we find the collision hazard likewise comprised of three components: the driver or occupancy hazard, which may be called a moral hazard; the exposure hazard of traffic or territorial conditions; and features of design, assembly and equipment of the individual automobile or makes of automobile. A very brief analysis is sufficient to show that, as with the fire risk, the first and second components of the collision hazard are not capable of detailed analysis as to make of car, and must be averaged through a basic or key rate with flat increments of credit or charge for territory and for psychologic influence according to experience, expediency, or both combined. As to the fire risk, these items are beyond the automobile builder's control.

It will have been observed that the third component of the fire and the collision hazards is identical, being the features of design, assembly and equipment of individual models or makes of automobile. It is this component that can be specifically analyzed and which is almost completely within the builder's control. It is for this common component that schedules are employed.

The procedure in developing the schedules was substantially as follows: All items of design, construction, assembly and equipment thought to have the slightest bearing, favorable or otherwise, upon the hazards being classified were listed. Following this, items related were grouped and weights were assigned to each group indicating their approximate influence on the total share which the physical features may have of the total hazard. During the entire development period the advice and assistance of adjusters and automobile underwriters were sought and secured. Frequent conferences were had with committees representing the automobile industry whose cooperation in the work of development of the schedule has been an important factor in its success. It was at the request of the Insurance Committee of the National Automobile Chamber of Commerce that, to avoid the implication of a manufacturers' liability under subrogation or other action, the schedules assume a practical car with a minimum of safeguards and record credits for desirable features.

Reviewing first the fire schedule, we find that 85 items are employed to measure the extent to which a given model of automobile may be preferred as to fire risk over the assumed car with the minimum of safeguards. These items are grouped in sections or subsections as follows:

Sec. 1. Fuel Storage
Subsections (1) Tank capacity
(2) Tank location
(3) Tank construction
(4) Tank mounting

Sec. 2. Fuel-Feed System
Subsections (1) Gravity feed
(2) Pressure feed
(3) Vacuum or pump feed

Sec. 3. Fuel Line and Fittings
Subsections (1) Tubing and connectors
(2) Gages
(3) Strainers
(4) Shutoffs

Sec. 4. Carbureter

Sec. 5. Electrical Equipment
Subsections (1) Wiring materials, installation, connections, supports and protection
(2) Devices
(3) Circuits

Sec. 6. Exhaust Line
Subsections (1) Position
(2) Muffler and muffler cutouts
(3) Exhaust heaters

Sec. 7. Miscellaneous and General
Subsections (1) Mud-pan
(2) Oil or gas lighting
(3) Workmanship, stability and salvage

The classification schedule provides some 8000 points of credit for a thoroughly safeguarded automobile job as compared with the assumed practical job with the maximum hazard or minimum safeguards. This range of 8000 credits provides an enlarged scale, as it were, and compares in its limits with the range in loss ratio shown by the 1918 statistics of the National Conference for some 30 makes of car for which net liabilities were listed in excess of $1,000,000. With such minimum net-liability involved it is assumed that the law of general average fully applies. Consequently, the exposure and moral-hazard components become a constant in the loss ratio and the range in loss ratio therefore reflects the influence of the built-in hazard. Having determined upon the constant for the exposure and moral-hazard components and combined with it a smaller constant to take care of a remaining possibly persistent hazard of self-ignition, a method of classification according to credits derived by schedule remains for determination.

It can be seen readily that by the use of the schedule an individual or specific method of classification is immediately possible and it is not inconceivable that such specific or individual classification or rating may be adopted eventually. Meanwhile it is entirely feasible to

utilize the skeleton of the list-price classification method with which the entire automobile insurance personnel is already familiar. The range of credits available under the schedule is split into classes as shown in Table 2.

TABLE 2—RANGE OF CREDITS AVAILABLE

Class Symbol	Schedule Credits
(For Passenger Automobiles)	
AAA, AA	available for future use
A	5,000 or over
B	4,500-4,999
C	4,000-4,499
D	3,500-3,999
E	3,000-3,499
F	2,500-2,999
G	2,000-2,499
H	under 2,000

The automobile insurance world is accustomed to the use of alphabetical symbols in connection with the collision and property-damage and liability classification. Therefore, no new or unfamiliar methods or practices are required of it in connection with a transfer to the schedule method when similar symbols are provided to indicate rate classes for fire and theft.

Considering now the 10 fire classifications established, at least for the present, we observe according to Table 2 that of the 8000 credits possible under the schedule, a total of 5000 only is required for assignment to Class A. The remaining 3000 credits are held in reserve, as it were, in the expectation of improvements in car design and equipment for which rewards of AA or AAA classification are promised. The five principal classes, A, B, C, D, and E correspond respectively to the five list-price classes and symbols which have been heretofore employed. Classes F, G and H are in the way of being penalty classifications in view of a serious lack of the safeguards commonly found.

One further point covering the fire schedule, with which we have dealt at length since its principle is that of the collision schedule and possibly of others as well, is that the symbolizing of cars and the classification indicated thereby in no way interfere with or dictate rates. The rate for Class A or AAA may be 1.0 or 0.1 per cent. The range of rate between Classes A and B, or B and C, or A or AAA and H may be as wide or as narrow as experience, expediency or other considerations require. Similarly, flexibility in a given range can be had through flat increases or decreases in the basic or key rate to distinguish between territorial or other circumstances of the business.

Substantially identical methods of analysis have been employed in the development of the collision schedule. The following examples will illustrate how feasible is classification by schedule of items of built-in design affecting the collision losses. Such items affect the collision loss ratio either by assisting to avoid collision or in the way of reducing extent of damage should collision occur. Of the latter group is the matter of radiator location. A certain heavy-duty truck has its radiator at the dashboard some feet to the rear of the forward cross-frame member which guards the engine and the hood from puncture by timber, pipes, tailboards and similar objects on other vehicles. Accordingly, in substantially the proportion of radiator-damage cost to the total collision loss ratio for trucks, credits are given in the schedule for this design as compared with the usual one. Similarly, in passenger-car jobs, a protected location of the radiator or its absence is recognized in the schedule by credits in number to indicate the relativity of this safeguard in the total of credits available.

Design Factors of the Fire-Hazard

As to the automobile fire-hazard from the viewpoint of design, it has seemed to me that the automobile industry has overlooked the fact that there is current in a storage battery. A storage battery can deliver about 500 amp. on an instantaneous discharge, can unload a large amount of current in 3 or 4 min. and melt any piece of wire if there is a good short-circuit. Instead of using the double-insulated circuits, manufacturers have grounded the car frame, because that is the easier and probably the cheaper way. I have seen unsoldered splices in the head-lamp and other circuits, instead of bringing the wires back to the switch terminal. In every case we understand that the reason for varnish-cloth insulation is that it also withstands heat and oil. It is easy to wire a car so that the wiring will not be exposed to oil. Battery slop will cause this insulation to rot for 6 or 8 in.; every time the hose is turned on it, the insulation will allow current leakage and some day there will be a short-circuit bad enough to set fire to the wood in the body of the car. The electrical hazard generally is a serious fire-hazard of automobile insurance.

There are a number of things to avoid in laying out the exhaust line. In one popular car the exhaust line lies about ½ in. above the engine-pan and over it is the carbureter, which drips. All carbureters flood and overflow. The "V" of the V-type engine is an excellent trap for this overflow and when the engine backfires the car burns. This design defect has been taken care of in most cases by installing a drain in the "V."

The breather is a severe fire-hazard. Unless the engine is washed every day, the oil vapor from the breather collects on the engine and ought to burn the first time there is a backfire or short-circuit forward of the dash. Backfiring is one of the frequent causes of fire. When a cold engine is started, a backfire will ignite the gasoline fumes before they are blown away. Automotive engineers should be able to do away with this fire-hazard; marine engineers have done so because they have had to do something to eliminate the foul smell and dirt around the breather. If something could be worked out for an automobile engine to burn up the breather fumes and wet oil so that the cylinder-block would remain clean, adequate consideration would be due in the insurance classification.

One of the meanest problems is the storage of gasoline and I have no patience with engineers who ignore it. It is not necessary to worry about gasoline while it remains liquid; it is the gasoline vapor that causes the trouble. The use of the engine-pan is an unexplained mystery; I do not know what good it does, at least for city driving. I took the engine-pan off of my car and it runs just as well. This pan is another very substantial fire-hazard in the equipment of automobiles. In addition to the engine-pan some cars have a leather boot all the way back.

From the collision viewpoint, consideration should be given to whether the side frame-members are heavy enough; I think these have been made too light. For example, a Ford car having a bumper hit another car; the Ford car was not damaged much, but the frame horns on the car it hit were bent from 25 to 35 deg., necessitating a very mean and expensive repair job that spoiled the looks of the car permanently. Automobile bumpers are doing much good. I feel sure that one of them prevented a serious accident to my own family.

approve of the modern practice of putting substantial tubular braces out near the front-spring horns, but on some the ends of the tube are simply stuck in and the splits turned over, so that they are liable to drop out when the car is running. If put in for rigidity, they should be properly secured.

The number of cases in which the drain-plug on the bottom of the tank is scraped off when going over country roads is surprisingly large. Sometimes conditions occur in driving where the rear-spring clearance is zero, and tanks drag on the ground. If the car is going fast, the tank is likely to be damaged.

THE DISCUSSION AT NEW YORK

J. S. MARVIN:—At Mr. Small's request the National Automobile Chamber of Commerce and the Society of Automotive Engineers appointed committees about two years ago to discuss the construction features of cars, because the Underwriters' Laboratories intended to work out a plan of grouping cars according to construction features rather than by list price, for determining the insurance rates on the various makes. The committees have had several joint meetings. One of the details that came up during the discussions is the matter of identification marks and whether it would be practicable to make it more difficult to obliterate them. I quote the present S.A.E. Standard for the maker's identification number[3] and following that, the engine-number Standard.[4]

> The Standard location for the car, chassis or frame number, whichever is used for identification, shall be on the outside flat of the right-hand frame-number, as far forward as possible. The characters, not less than ¼ in. high, shall be heavily indented in the frame side-member. When this location is inaccessible, it should be approximated. The use of attached plates in place of characters stamped as specified is not desirable because of the ease with which a plate can be removed.
>
> The Standard location for the engine number shall be on the crankcase proper, at the front end, as near the middle, crosswise, as practicable, and on top, if possible. Consideration should be given to accessibility in the completely assembled vehicle. If it is not possible to locate the number near the center at the front, that position should be approximated, preference being given to the right-hand side. The characters, at least ¼ in. high, should be deeply indented in the crankcase.

It will be noted that the only description of how the numbering shall be done is that the characters shall be not less than ¼ in. high and be heavily indented in the frame side member. At one of the recent meetings of these committees it was decided that steps should be taken by the Standards Committee of the Society to make the changing of these numbers more difficult. Requests for suggestions were sent to a large number of engineers and to car, frame and engine builders, and about 65 replies have been received. Inquiry was made regarding present practice and possible changes, three suggestions that had come up in our committee meetings being mentioned, not with the idea that the voting was to be confined to them, but for the purpose of encouraging further thought.

The first suggestion offered might be termed a checkerboard plan, involving casting a series of numbers on the engine or a plate; digits were to be drilled out and plugged and the drill run through into the engine casting or frame member to mark permanently the digit drilled. The system consists of a series of numbers reading from the top to the bottom, 1, 2, 3, 4, etc., and crosswise, the idea being to drill them out so that the number can be read. The next suggestion contemplated stamping numbers, preferably of the script type, into the frame or casting to prevent changing easily from one number to another. The third suggestion was to use a number cast directly on the casting. The great disadvantage of this plan is that defective castings would interfere with the consecutiveness of serial numbers. Still another thought was to stamp numbers deeply into the frame or casting with a thin knurl, to make it still more difficult to change the number impression. This plan received considerable approval. About one-half of the replies recommended continuation of the stamping process, which is practically the present S.A.E. Standard so far as the type of numbering is concerned. One suggestion is that several parts other than the engine and the frame bear numbers, and that a record be kept of such numbers on each car. Unless all the numbers were located and changed, identification of the car might still be possible.

Speaking directly for the National Automobile Chamber of Commerce, it is our thought that it is very well to try to prevent the theft of cars but as long as there is a ready market for stolen cars and as long as there is a great incentive or, to say the least, no objection on the part of car owners to having their cars stolen or burned up, the answer to this problem will not be found. A friend told me recently that his new car last year was insured for $2,600 at a cost of $33.80. This year his bill for renewal shows that he is covered for $2,500 at a $55 premium. He said he would gladly take $2,000 for the car. Not long ago we learned of a number of cars having been found in Lake Erie, near Buffalo; six more were found in a quarry in Illinois. A police officer noticed recently the top of a touring car sticking up out of the water in New York Harbor and had it fished out and traced to the owner who said it had been "stolen." Such things undoubtedly are going on because of the high coverage. We doubt very much whether the insurance companies should cover cars to the present extent. One thought is that not more than 75 per cent of the value of the car should be written and in that connection possibly the depreciation should be provided for as cars get older.

The moral hazard has been increased very greatly during the last two or three years. It is likely that, within that period, many people have owned cars who could not afford them. Regarding fire, we seldom hear of a car that burns up in a densely populated district; the fires usually occur in some isolated spot. This seems to be significant. In our opinion insurance companies should apprecate the fact that in writing automobile insurance they are dealing with a different problem than when writing other forms of insurance. An automobile is an article that can be made away with very readily. The methods that have been applied, in other lines, of writing insurance for anyone for any amount he wishes, will not do at all for automobile insurance. The selling of stolen cars must be made difficult and the incentive for having cars stolen, the owner's indifference, must be eliminated by reducing the coverage, before the real solution of the problem will be reached.

CHAIRMAN H. W. SLAUSON:—The automobile insurance underwriters themselves maintain a detective bureau. Harry M. Shedd, director of that bureau, will now describe the methods employed by the underwriters

[3] See S. A. E. HANDBOOK, vol. 1, p. K41.
[4] See S. A. E. HANDBOOK, vol. 1, p. A13.

in recovering stolen cars and in apprehending and prosecuting the thieves.

HARRY M. SHEDD:—In February 1917 five companies saw fit to combine in an endeavor not only to prevent the theft of cars in some degree, but to make recovery by way of salvage. The bureau formed has grown until it now represents the entire membership of the Eastern and New England Underwriters Conference, composed of about 106 insurance companies operating in the United States and Canada. One of the first things done was to install a complete card-index system. When a car is reported by a member as having been stolen, an effort is made to ascertain whether the car number is correct. After we have been satisfied as to this, we send the number to the factory on a card prepared for that purpose and all component part-numbers are filled in there. These component part-numbers are cross-indexed. The names of the assurers also are alphabetically arranged. In addition, the car numbers and the engine numbers are numerically arranged. Whenever a stolen car is found by the police, even if both the engine and the frame number have been removed, we are able to ascertain at once the true engine and factory number of that car when we refer to the master index-card on which all the numbers are recorded. We are getting splendid cooperation from police departments throughout the country, and we are attempting to furnish information that will lead to the apprehension and incarceration of the thieves. But we are handicapped. We have an abundance of laws. What we need is judges who will, rather than parole prisoners, send them to jail for the moral effect. A great number of cases are brought to court by police officers who have worked tirelessly on them, apprehended the thieves and secured confessions, but the magistrates parole the thieves.

Our statistics show that less than 1 per cent of the total number of cars recovered by our men and also of the cars recovered by the various authorities throughout our district, have approved locking devices. In other words, the thief travels the line of least resistance and takes cars that are not locked. Many owners leave their cars thinking that they will be absent only for a minute or so and that it is not worthwhile to lock them. Thieves who wish to steal cars watch where the owner goes and it is within the first few minutes after a car is parked that it is stolen.

No two thieves work alike; organized gangs and many "master" minds are at work. Since our bureau was organized we have had only five cases in which there was some doubt whether the lock had been picked. One of the great troubles we have is our inability to get proper numbers from factories which fail to keep component-part-number records. Many car builders are efficient in this respect. They furnish quickly all information, by telegraph, telephone or letter, which makes possible the identification of a car. Others keep no records and, when we have visited the factories and attempted to find through our own search the whereabouts or the legal owner of a car that they have shipped, we have found this impossible. I believe that the standardization of a secret engine number, which it would be impossible to eradicate, is the solution of the matter so far as the identification is concerned.

The ignition lock is unsatisfactory. Some firms will even go to the extent of having Yale locks with 200 key-changes. They think this is a sure safeguard against theft, but all that is necessary is to open a closed circuit or to close an open circuit, and any car can be driven away within a few minutes by thieves. But we find that they will not take time to pick a lock which would make the car inoperative or at least give some trouble.

The apprehension and conviction of thieves would seriously interfere with the traffic in stolen cars, especially if the thieves were made to talk. It is true in some respects that the insurance companies are to blame largely for writing insurance on questionable cars, but it must be taken into consideration that, when the price dropped in automobiles, the cars that were insured for a fair market value then went to a premium; the people who wished to sell them, finding that they could not sell them otherwise, sold them to the insurance companies for practically what they paid for them. It is my contention that an insurance company cannot consistently make a complaint against an automobile, because at the time the theft occurs the insurance companies have no official stand in the matter. The complaint is against the State and the owner is not entitled to collect the claim until the matter has been turned over to the insurance company. I believe that the insurance companies should not make the complaints, for the simple reason that they are not interested parties until after the claim has been paid. Although they are interested financially and may ultimately have to pay the claim, the title does not pass to them until the claim is paid. If there were no market for stolen cars, if the stolen-car market could be destroyed and a penalty imposed which would be more severe for the receiving of a car than for its theft, the theft of cars would certainly decrease. The United States Department of Justice has been very active lately in the apprehension of thieves and prosecution where interstate-traffic theft has occurred; this has curbed the theft of cars to some extent. Our experience has taught us that the theft of cars from garages where the locks are picked, occurs where a person has all night to take the cars away, but these cases are rare. When a car is placed in a garage and the owner insists that the car be left unlocked, the dishonest employe has a chance to make a wax impression of the key and await his chance to steal that car. Further, we find that the thieves take out license-plates several days ahead of the day the car is to be stolen, and have the particular car they are looking for registered after the theft occurs; or they can go to the Secretary of State's office and give whatever number comes to mind, and have that particular number put on the engine of the stolen car.

Bills of sale do not mean much for the reason that if they are not properly inspected there is no law for the punishment of the people who issue fraudulent bills of sale, unless they do this knowingly. The notaries all hide behind the statement that they did not know the car was stolen and that they have only acknowledged the signature. In that connection we have found that the automobile thief is usually very friendly with some particular notary, which makes it hard to prove that the man who received the car knew he was purchasing a stolen car. We issue an alarm sheet daily that covers all of the cars stolen, but unfortunately these give only one manufacturer's number. That is because people who have cars insured do not give the insurance companies the proper number; whereas they should give both engine and frame number, they only give one. We attempt to ascertain whether this is the engine or the frame number but, even in the case of cars that bear both the frame and engine numbers these are sometimes transposed and several days are lost in finding out what the number referred to is.

Formerly when a man went in to report to the police that his automobile had been stolen, they made a note of it and promptly forgot it, but that condition is changing. Most cities are organizing police squads that devote their entire attention to the theft of automobiles. These men become efficient and can identify stolen cars quickly. The difficulty for both the police departments and our bureau lies in the fact that the owner will not equip his car with a suitable approved lock. In many cases, unless the lock is very easily operated and can be readily reached, the owner will not lock his car at all. If all cars were locked and the owners could be educated to keep their cars locked, the theft hazard would be reduced materially.

MR. O'HANLON:—When I was engaged in the building of cars, after getting out a somewhat elaborate system of identification marks we finally came to feel that this was a matter for someone else to take care of and that after we had put a number on the car our duty was done. I think that is more or less the idea among builders today and as a result the thief has little difficulty in removing all means of identification from a car.

In the case of one Hudson car that was recovered 11 of its 13 identification numbers had been removed. One identification mark consists of a washer. This has a number, known to us, on it. After discs like it have been placed in various parts of a car it is practically impossible for a thief to remove them all without taking down the entire car; because their number varies from 5 to 15; otherwise he would never be certain that he had found all the washers even though he might have found several. In addition to this disc identification service, we furnish a plate which is placed on the radiator for deterrent purposes. The plate is removable, but I know of nothing that cannot be removed from a car. It serves the same purpose as the detective-agency notification plate over a banker's window and was prepared, authorized and approved by detective agencies that are affiliated with us. Another advantageous feature of this identification system is that it is automatic in action, and one does not need to lock his car.

The question often arises as to the inspection of cars and the proving of ownership. An automobile title insurance company, affiliated with the company I represent, is now in process of organization. Its work will be to appraise and make physical inspection of cars, to determine whether any numbers have been changed. So far as the insurance companies are concerned, they can insist upon proof of ownership. This would eliminate many of the troubles of police departments and other officials engaged in the recovery of stolen cars.

A. R. SMALL:—In testing a lock submitted for classification we make a bench test or a driving test, as the manufacturer of the lock may prefer. We first consider the method of operation of the lock, and then ask the manufacturer to state for what makes or types of automobile he proposes to sell the lock. We receive many kinds of gearshift lock that are not suitable for some car models. It is useless to consider a free steering-wheel lock for a car which has 3 to 5 ft. of the steering column, not the outside enclosing case but the real steering post, exposed in the driving compartment. It is easy to steer such a car by using a stillson wrench.

We assemble the lock on a bench or in a car in substantially the manner it is designed to be operated. In the case of locks equipped with Yale-type keys, our first effort is to remove the locking cylinder. Very frequently that can be done with a ½-in. cold chisel and a ½-lb. hammer. After about six knocks into a gray-iron casting one can take off the whole cast-iron housing around the cylinder, withdraw the cylinder and then manipulate the locking bolt with one's fingers or with a screw-driver at will. A locking cylinder must be housed in a material of sufficient elasticity, ductility and strength to resist such ready and easy attack. Very frequently the lock cylinders are retained in place by set-screws. We have had locks from which when mounted on a small vibrating machine and operated for a few minutes, representing perhaps 3 or 4 miles of riding on a rough road, the set-screws would back out and the locking cylinder fall out.

Certain types of lock employing Yale keys can be broken into or picked with an ordinary screw-driver. The tumbler-pins inside the cylinder may be spaced so that perhaps only ⅛ in. of one pin is actually locking the whole bolt. By putting in a screw-driver or taking a pair of gas-pliers and getting hold of the real rotating member of the lock and cylinder, one can shear that locking pin off. Very frequently the submitter of the lock claims that the work has been done expeditiously or more easily because of the bench assembly; then we request him to submit an automobile with the lock mounted in it and proceed to defeat the lock in substantially the same manner as in the bench test. It is not feasible to explain in exact terms what our procedure is, because locking devices all differ, one from another.

Practically the first lock to be put out in any great number was a loose steering-wheel lock for Ford cars. It seemed to be a good thing but was soon shown to be ineffective because thieves were stealing the cars. In the steering mechanism of the Ford car there is a pinion in the spider hub that drives what looks like a planetary-gear system. The locking device withdrew this center pinion from engagement with the outside gears and held it out of engagement by means of an ⅛-in. steel washer. Investigation showed that the thieves were tapping the nut on top of the Ford steering mechanism with just a light blow of a hammer; in perhaps 60 per cent of the jobs they would succeed in dishing the washer sufficiently to permit the center pinion to engage about ⅛ in. with its gears and thus steer the car. We now require that this particular washer be made of a different grade of material, so that it cannot be bent so readily and we have kept that feature in mind in connection with every subsequent lock that is submitted. Our regulations are to the effect that it should not be possible to get away with a car under its own power in less than 20 min. with the tools available to an ordinary garage mechanic or one of our own engineers. That is not a very serious test if one considers how much an expert mechanic can do to an automobile in 20 min. The tools used are an ordinary 2-lb. mechanics' hammer, a cold chisel not exceeding ¾-in. edge, screw-drivers of any size, gas-pliers, ordinary pliers and a small stillson wrench; usually we can drive a locked car away in 20 min. with that apparatus. However, this all involves an opportunity on the part of our engineers, prior to the test, to study the locking mechanism and consider the methods of operating the car. One popular make of car that is very frequently stolen is being equipped with a factory built-in lock. It is rather a good lock and would impress many engineers and insurance company officials favorably. Our engineers studied it from the viewpoint of the operating mechanism of the car itself and not as a lock. It is a gearshift lock. In studying the mechanism and the way of operating the transmission and the effect of the application of the lock to it, we found that it was only necessary to lift the floorboards from the car and to make a certain shift with a

screw-driver of the shifting fork through a hole in the transmission case cover; whereupon the car could be put in first speed and driven away. A transmission working in first speed does not seem effective to the automobile engineer or the factory man, but the thief can get the car around the corner, drive it possibly ¾ mile and get it into some abandoned stable or a friendly garage. To drive a car in first speed for 20 to 30 min. is nothing to a thief, considering the reward he expects to get. If a thief knows the mechanism of a car and has an idea how the locks work from having gone into a dealer's store and looked them over, he can discover how to use the gearshift to get the car out of the way. I have heard stories of cars being driven from ferryboats up steep hills with the storage battery in emergencies. That is one way of defeating many of these locks. The destroying of a storage battery means nothing if the thief gets a $5,000 or a $10,000 car. We require further that the lock of the car shall be operable from the driving compartment, because it will not be used frequently if located elsewhere.

JOHN G. PURDIE:—I wish to bring up the matter of cooperation from the State authorities with regard to licensing, to which I have given much attention. Regarding the effort to have the second-hand-automobile dealers placed on the same basis as the pawn-brokers, that would be a very useful thing. In the State of Maryland the law requires that a traveling deed to the car shall be held by the owner. This matter of State legislation can be appreciated better when it is remembered that in the case of real estate bought for $50 the law requires stringent regulations to be observed with regard to obtaining title to it, registration and the like, but that no precautions are required with regard to a mobile piece of property worth perhaps $10,000. Any policeman or State officer in Maryland can demand the title deed to a car if it is registered under the law of that State, and if a car driver cannot produce it he will be locked up until he does produce it; so, we do not lose Maryland cars very frequently.

The registration system in New York State is practically useless for the purpose of recovering stolen cars. A record of the license number is kept in the office of the Secretary of State, but when a specific license number is inquired for about 10 days or two weeks is likely to elapse before the name and address of the owner of that car is furnished. Pennsylvania has a triple registration system which is very efficient. The car is registered under the make, the engine number and the owner's name. If one wants to know about a car and its owner in Pennsylvania, the Secretary of State's office can furnish the information quickly. These things are very important in the matter of making it more difficult for the thief to dispose of stolen property at any price and that is the most effective deterrent to the commercialized stealing of automobiles.

RICHARD COLEMAN: — During the 1921 Automobile Shows at New York City and Chicago I took up with a number of lock manufacturers the matter of an educational campaign. We have been told that practically only 1 per cent of recovered stolen cars were found locked; generally it is the unlocked car that is stolen. There are many good locks on the market that have withstood severe tests but the main point is one of education. Any salesman of automobile locks knows the truth of the statement that the average man who is insured does not care whether his car is stolen or not. I think that this attitude on the part of the average owner has been responsible for the action of the National Automobile Underwriters Conference in placing a $15 penalty premium on all insured cars which do not have an approved lock; and raising that penalty to $25 in New York City this year. It is simply a question of forcing people to lock their cars. I am firmly convinced that if the Society of Automotive Engineers, the National Automobile Chamber of Commerce, the Motor and Accessory Manufacturers' Association and the Underwriters would institute an educational campaign to "lock your car," car theft would be eliminated to a very large extent.

CHARLES J. EVERETT:—Although we have heard much about the stealing of cars and the methods of protection, it seems to me that we have not arrived at any definite conclusions that put us in a position to take effective action. I agree with those who say that locks, although something of a deterrent, will not stop the stealing of cars. I believe that we must obtain changed legislation in all the States, because changing it in one State alone will do no good; and further that the penalty for purchasing a stolen car should be made so heavy that it would act as a very great deterrent. Some legislation should be put through in the form of requiring an absolute clearance deed from the Secretary of State; if a man buys a car that does not have the original number on it or if the car number cannot be verified, he should be subject to a very heavy fine and should forfeit the car. Some definite lines of action should be determined with the idea of getting the matter eventually through the legislatures. If it becomes known that we are trying to take legislative means to stop the stealing of cars, that will be something of a start even though it may fail.

R. H. GOODWIN:—It has been intimated repeatedly that the insurance companies are not doing all that they can do to cooperate with the police departments and the general public in reducing this theft evil. The National Automobile Underwriters Conference represents substantially all of the stock insurance companies doing automobile insurance business in the United States, and I have had opportunity as its assistant secretary to follow very closely all of the legislative and other work that has been accomplished by its several committees. Unfortunately, we cannot do all that we would like to do because the business is subject to the various laws of the several States. The insurance business is peculiarly susceptible to State supervision. Each insurance commissioner has certain ideas that he thinks should govern the conduct of the business in his particular territory; few of them have the same viewpoint. That is, perhaps, one reason why the Conference has failed in some instances to adopt and enforce its uniform standard forms and practices.

The Conference has not been unmindful of the growing theft evil that has been discussed so much here this evening. As evidence of that fact it was announced to the general public, through the insurance papers, that as of May 1, 1921, the so-called valued form of automobile policy would be discontinued. We feel that this was one long step in the right direction. The car owner is more likely not to pay a premium on an amount of insurance in excess of what can be reasonably construed as the intrinsic value of the car at the time of loss.

The Chicago Crime Commission recently called upon the insurance agents in Chicago to cooperate with it and do something to reduce, if possible, the tremendous increase in thefts there. At that time we drafted a new form of theft policy, or an endorsement to be attached to the present theft policy, that provided for the exclusion from the coverage in its entirety of any liability for the

theft of tools, repair equipment, engine meters, spare tires, extra tubes, rims, ornamental fittings and other accessories. We went a step farther and made it a condition of the policy that the liability of the company for loss or damage caused by theft should not exceed 75 per cent of the actual amount of loss sustained.

Mr. Marvin stated that he thought the insurance company should not write more than 75 per cent of the value of a car. This particular form of policy is operative today in Chicago, and in Cook County, Illinois. It is on trial there, but it has not yet been adopted elsewhere. The business of an insurance company is to insure, and it is maintained by many that the insurance company cannot accept a man's premium for a certain amount of insurance and then pay him a less amount when he has a loss. The business of automobile insurance today covers against loss of or damage to automobiles; but the same companies are dependent for their principal income upon the regular commercial fire insurance lines which, in most instances, are their main lines of business. The automobile insurance business has been handled as a sideline from its inception up to the present by many of the companies. In many instances the insurance companies took on the automotive coverage to protect their fire insurance interests among agents who said that they must have every kind of protection that the public demanded. As a result, a few companies started an automobile insurance department, but it was treated more or less as a side issue. Automobile insurance has now achieved a prominent place in the insurance world.

The Eastern Automobile Underwriters Conference recently adopted a rule whereby it is mandatory for owners whose automobiles are not equipped with an approved locking device, to pay a $25 penalty charge in the boroughs of Manhattan, Brooklyn and the Bronx, New York City. The companies do not feel that tremendous increases in rates is good business. If the cost of insurance is increased to such an extent that it becomes virtually prohibitive, the companies will have practically ruined their business. We are beginning to feel that it is no longer a question of the rate and that something else must be done. The owner of the car must be made to realize that he has an interest in his insurance and an obligation to the public. Possibly this 75-per cent loss clause that is being tried out in Cook County, Illinois, may accomplish this. We are watching the results there with much interest. However, I wish to emphasize that the insurance companies, through the National Automobile Underwriters Conference, are certainly very much alive to the situation and, if it is at all possible to bring about the results we all want to attain in some other way than by increasing the cost of insurance, we want to find that way; but we want to be sure that we have found it before we put it into effect.

ETHELBERT FAVARY:—I speak from the automobile engineer's standpoint. The use of numbered identification washers placed at various parts of the automobile seems to me to be inefficient. When a police officer stops an automobile, how can he look for those identification marks? Of course, there is no way of marking an automobile to preclude entirely the possibility of obliteration, but some means can perhaps be devised to make this more difficult. I wish to mention a method by which a police officer could identify a car very quickly. It consists of raised letters on the water-jacket. Supposing those letters were ½ in. high, hollow on the inside, and that the jacket wall were 5/32 in. thick, and that the hollow part of the letters projected 3/16 in. beyond the outside of the water-jacket, it would be difficult to obliterate such marks, and one could tell whether the outside of the jacket casting has been patched or defaced.

In regard to proving title, I suggest that when a car is first sold the factory's bill of sale be a document on which the builder places his stamp, and that then the police department or a branch of the State department be required to stamp the bill of sale to confirm it. This same document should accompany the car at each transfer to a new owner. When the car is sold the owner should present that same document for stamping by the State or police officials; in this manner anyone could tell where the car came from originally and trace its ownership. If such a method were adopted it would, I believe, be very difficult for a thief to dispose of a stolen car.

M. C. HORINE:—In matters of this sort, as in medicine, we are apt to treat symptoms instead of causes. The prevalence of car stealing is a symptom of a cause which is a mental attitude and has been referred to as the "moral hazard." The moral hazard consists of an attitude of mind on the part of the general public, those who are charged with the enforcement of law and those who are charged with the interpretation of the law. In the early days of this Country the horse was regarded as one of a man's most useful and valuable possessions and the horse-thief was regarded as the lowest of criminals; so much so, I believe, that more men were lynched for horse-stealing than anything else. On the other hand, now that the automobile has replaced the horse in our civilization and such low beings as car thieves have appeared, they are regarded as rather clever; we would like to have them as mechanics, because they are so ingenious in circumventing the efforts of the lock inventors. The general public regards the car thief in nothing like the same light that our forefathers regarded the horse-thief. I think that this is the crux of the whole situation. We cannot get at the solution of this problem by locks because, as in military science, we find that there is no gun so powerful that armor or fortifications cannot be devised to resist it, and by that same principle there is no fortification or armor so impregnable that a gun cannot be found to pierce it.

What we need is, in the first place, just legislation dealing with the car-thief; a public sentiment, fostered by education, that will insist that jurists mete out justice to these offenders; and legislation that will make it possible to establish the ownership of a car. Insurance against car-theft as it exists today is only an aggravation to car thievery.

ADRIAN VAN MUFFLING:—One of the speakers mentioned that under present conditions it is impossible to raise the rates, but that it is possible to put a 75-per cent loss clause in the policy. It seems to me that this is the same thing. Paying 75 per cent of the actual loss sustained really amounts to raising the rate 33⅓ per cent, does it not?

EDMUND ELY:—We must consider two hazards; the interior hazard and the exterior hazard. The first is the hazard of the owner himself, what we in the insurance business designate as the moral hazard. The second is the subjection of the property to depredation by automobile thieves. The interior hazard, to my mind, is by far the greatest factor in the theft situation today. We recognize that certain palliative measures, such as locks and the stimulation of police activities, will remedy the situation to some extent, but in the face of an economic condition such as we are now experiencing it seems to me that nothing else can be expected than a very marked

increase in automobile thefts. We have a very unique situation. Notwithstanding any care that may have been exercised by underwriters in the underwriting of automobiles, last fall we had an automobile market that was all shot to pieces; reduction followed reduction. We are now experiencing a recurrence of the same thing and we do not know how far it will go. No matter what may be done by underwriters or how much care and foresight may have been exercised, I think we cannot be charged with negligence in not foreseeing that condition. With a piece of property insured for $2,000, if the bottom drops out of the market and the owner of particular piece of property knows that he can get only $1,000 for it and it is insured in such a manner that no active measures are necessary on his behalf to protect that piece of property, he is likely to have an accident; the theft experience is directly due in a very large measure to that condition.

I do not wish to convey the impression that the insurance companies generally are not appreciative of the good work that has been done in these alleviatory measures, such as the perfecting of locks and various other devices, but there are only two absolute preventatives of theft. First, the interior hazard can be cured only by assuring to the insured that in the event of loss by fire or theft he will recover only the actual market value. The incentive for him to be careless with his car will thus be destroyed. He might just as well sell it, because he cannot recover from the insurance companies any more than he could sell it for. The other measure is an absolute transfer of title in the same manner that realty is transferred. I do not say that this is advisable. I do not know whether it is the proper thing to surround traffic in automobiles with such restrictions, but it is the only thing that can absolutely destroy the marketability of the article and prevent thefts from the exterior hazard.

Apart from the unsettled condition of the automobile market, the bane of the insurance business is the over-insurance of cars. While I have commended the insurance companies in the face of the adverse conditions that existed in the past 12 months, I cannot but conceive that there may have been some laxity in that particular, and perhaps the experience that we are now undergoing will have a salutary effect in correcting it. However, I wish to have it borne in mind that the insurance business is in no wise different from any other commercial business. In the face of strenuous competition it is possible that the insurance companies may have over-stepped the boundary somewhat and no doubt there has been competition between insurance companies on the basis of the amount of insurance that they would be willing to grant; but it may be within your knowledge that even in the automobile trade it has been charged that while the members have an agreement to maintain list prices and would not reduce them, still they would allow an exchange of twice the value of the traded-in cars. The two situations are more or less analogous. Admitting that there are conditions that are detrimental to the welfare of the business, still we are unable to prevent them. Of all people the underwriters do not want high rates. We realize that when rates increase to such an extent as they have increased in automobile insurance, the very fundamentals of the insurance business are attacked. That is something we must avoid at all costs.

LEON OTTINGER:—I believe that any information which will assist the insurance companies to decrease their rates of insurance will be welcome. A young man in my office who owns a car had a slight collision. He had the manufacturer give an estimate of the cost of repairing the damage. The estimate was $85. The insurance company sent their adjuster to examine the car, and the owner was told that the repair would cost $350. It was discovered that an estimate for this amount had been submitted to the company by a son of the adjuster. The owner was exceptionally honest, and gave the information to the insurance company. If the insurance companies would make sure that their repairmen and adjusters are thoroughly honorable, they might be able to reduce their rates.

MR. SMALL:—It seems to me that we are going through a period in which we are all looking to law and to government for help. About 45 per cent of the suggestions that have been made here for curing automobile theft have referred to the passing of laws and asking the police or some other body to do something.

W. E. KEMP:—What measures do the insurance companies employ to compel the users of automobiles to lock their cars and how do they know whether the cars were locked or unlocked when they were stolen?

MR. SMALL:—I do not understand that there is any compulsion on the part of the assured to use the lock, other than the moral compulsion to observe the requirements of the locking-device endorsement in the conditions of his policy, to give it due diligence and care. What chance would an insurance company have to get a favorable decision from a jury, in case of attempting to refuse payment on a loss because the owner forgot to lock his car? No company will attempt to refuse to pay the loss because the car was not locked or the lock was not used, because the American public and the usual jury are against the insurance company and for the car, or the property owner, in every instance. Educate the automobile owner to put a lock on his car, to watch his car and not to leave it in places where it ought not to be. It is simply a matter of education all the way through and not one of the law or anything else.

THE DISCUSSION AT CLEVELAND

Mr. SMALL: The statistics show that closed cars are not being stolen as much as open cars. About 147 different makes of passenger car are listed by the insurance companies, and about 35 makes represent 95 per cent of the insurance liability. In other words, the output of the builders who are producing 9 or 10 cars per month does not affect the insurance records. After a car is four or five years old thieves will not take it. There was formerly a market in making such cars over into trucks. The statistics indicate the approximate loss ratio and cars are put into the classes to which they seem to belong, the rates being determined by the record for the preceding year.

One automobile builder that keeps an accurate card-index of the different identification numbers, claims that it costs $40,000 per year to maintain it. Many automobile factories do not attempt to keep such a record. One of the things that has been considered is a superior method of identifying cars. With a set of numbering tools, a cold chisel and a light hammer the number on a car frame can be changed to any number desired. Some numbers are on a brass tag. In many cases the serial number on the engine is in ⅛-in. figures stamped on the casting; it is easy to remove this with an emery wheel and put on a new number. I told the National Automobile Chamber of Commerce committee that I refused to admit that serial numbers could not be put on so that it would be practically impossible to obliterate them with-

out evidence of the marking having been defaced. The insurance companies have offered a reduction in the rate against theft of about 7½ per cent for a standard acceptable method of numbering the frame or the engine. We will not accept the first thing that comes out; it will be sent to the police departments and their experts will try to defeat the system.

K. B. BRITTON: There seems to be a rate on liability insurance according to the make of the car.

Mr. SMALL: The companies are still trying to rate the cars according to list price.

A MEMBER: Does the year the car was built have anything to do with the rate? Is the rate based on the original list price of the car?

Mr. SMALL: A large percentage of new drivers drive new cars. The whole matter of liability is one of insurance actuary methods; it is bookkeeping and accounting.

A MEMBER: Is any allowance made on account of the design of the brakes?

Mr. SMALL: No, our schedule requires at least two independent braking systems. More fires are caused by brakes on the transmission than by brakes on the rear wheels; they lock more easily and are close to the floorboards.

A MEMBER: Is any reduction made for having brakes on all four wheels?

Mr. SMALL: No.

A MEMBER: Do pressure-feed gasoline-tanks cause any difference in rate?

Mr. SMALL: Yes; everything else being equal, the rear tank with vacuum feed is the best and the pressure feed is next. No credit is allowed for gravity feed.

R. J. NIGHTINGALE: An insurance agent told me that theft is the starting point of practically all losses. If a car is found burned up, the most likely reason is theft; if there is a collision or property-damage, it usually can be traced back to theft.

A MEMBER: Do any cities have an ordinance requiring cars to be locked?

Mr. SMALL: I believe Detroit has one, but it is not enforced.

A MEMBER: In connection with design, has it not been the habit of designers to do away with metal toolboxes?

Mr. SMALL: I think we have not considered that.

Mr. NIGHTINGALE: The insurance man I referred to said that if the theft of cars were cut down by engineering, much money could be saved. One of our officials pays about $100 per year for $2,500 insurance against fire, theft, and property-damage; but I pay $130 on my car on a $1,200 valuation.

Mr. SMALL: If a certain car were insured against everything, it would cost about 70 per cent of the price of a new car for the first year's insurance.

Mr. NIGHTINGALE: One man has the same kind of a car as mine and lives in an adjoining county; he pays less than half the premium I pay and drives in town as much as I do. That is unfair.

Mr. SMALL: If every individual situation were investigated, the cost to all would be prohibitive. It is necessary to make an arbitrary rule.

GENERAL STATUS OF TECHNICAL EDUCATION

A SUMMARY of the registration statistics for the years 1919-1920 and 1920-1921, as compiled from the reports of 81 engineering colleges located in 36 states, presents some interesting facts. It will be noted that, with respect to the total registration, all courses except chemical engineering showed a gain this year over last. In the case of the freshman registration, on the other hand, a loss is shown in every instance. During 1919-1920 the freshman registration amounted to 43.8 per cent of the total college registration, while this year the freshmen were 37.4 per cent of the total number of students.

TABLE 1—SUMMARY OF RETURNS FROM 81 ENGINEERING COLLEGES, SHOWING BOTH TOTAL AND FRESHMAN REGISTRATION

Course	Total Registration			Freshman Registration		
	1919-1920	1920-1921	Gain or Loss	1919-1920	1920-1921	Gain or Loss
Mechanical	11,693	12,159	+ 466	5,089	4,607	— 482
Electrical	11,285	12,118	+ 833	5,487	5,089	— 398
Civil	8,469	8,592	+ 123	3,612	3,046	— 566
Chemical	6,588	6,486	— 102	2,652	2,249	— 403
Mining	2,252	2,431	+ 179	903	780	— 123
Miscellaneous	6,018	6,526	+ 418	2,614	2,302	— 312
Total	46,395	48,312	+1,917	20,357	18,073	—2,284

The figures as summarized in Table 1 show that mechanical engineering is the most popular course in our technical colleges. This year 12,159 students were registered in this specialty and last year 11,693, a gain of 466. Electrical engineering runs a close second, the figures for this and last year being respectively 12,118 and 11,285, or a gain of 833. Civil engineering comes third with 8592 undergraduates this year and 8469 last year. Chemical engineering, with about 6500 students for the past 2 years, takes fourth place, while the mining engineering course, in fifth place, shows a considerably smaller registration than any of the others, 2431 this year as against 2252 last year. A reference to Table 2 indicates the percentage relation of the registration in the several special courses to the total and also the freshman percentages.

TABLE 2—PERCENTAGE RELATION OF SPECIAL COURSES TO TOTAL AND TO FRESHMAN REGISTRATION

Course	Per Cent of Total Registration		Per Cent of Freshman Registration	
	1919-1920	1920-1921	1919-1920	1920-1921
Civil	18.2	17.8	17.8	17.0
Mechanical	25.2	25.2	24.7	25.6
Electrical	24.3	25.1	27.1	27.8
Mining	4.8	5.0	4.5	4.3
Chemical	14.2	13.4	13.1	12.5
Miscellaneous	13.3	13.5	12.8	12.8
Total	100.0	100.0	100.0	100.0

FOURTEEN PASS 1000 MARK

Fourteen of the colleges are giving engineering instruction to 1000 or more students. The highest registration figures are reported by the Massachusetts Institute of Technology, Cambridge, Mass., with 2747 students. Next in point of size comes the University of Michigan, Ann Arbor, Mich., with 2212; third, Purdue University, Lafayette, Ind., with 1845; fourth, Cornell University, Ithaca, N. Y., with 1825, and fifth, the University of Illinois, Urbana, Ill., with 1818. The other nine institutions above the 1000 mark are, in order of size, as follows: Ohio State University, 1473; University of California, 1323; Georgia School of Technology, 1307; University of Minnesota, 1284; Pennsylvania State College, 1233; Texas Agricultural and Mechanical College, 1169; University of Wisconsin, 1150; Rensselaer Polytechnic Institute, 1039; and Iowa State College, 1011.—*Engineering News-Record.*

Lubrication of Timing-Gears

By E. Planche[1]

Illustrated with Photographs

THE tendency to simplify the design of engines has led a great many designers in the past few years to lubricate the timing gears with oil coming from the crankcase, instead of using a separate system of lubrication for the gears. This practice is

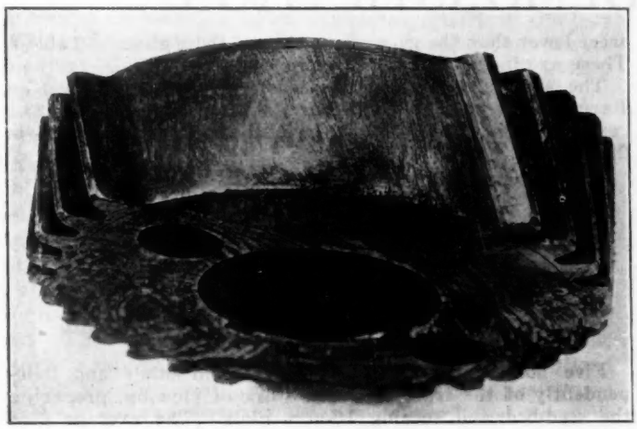


Fig. 1—A Crankcase Gear That Was Lubricated with Crankcase Oil as It Appeared After Running 10,000 Miles

very commendable in itself as it permits the car owner to lubricate the engine bearings, the cylinders, the pistons and the timing-gears by the simple operation of filling the crankcase with oil to the proper level and letting the engine do the rest of the work.

I used this system on an engine four years ago, to replace a system of lubrication of timing-gears, using

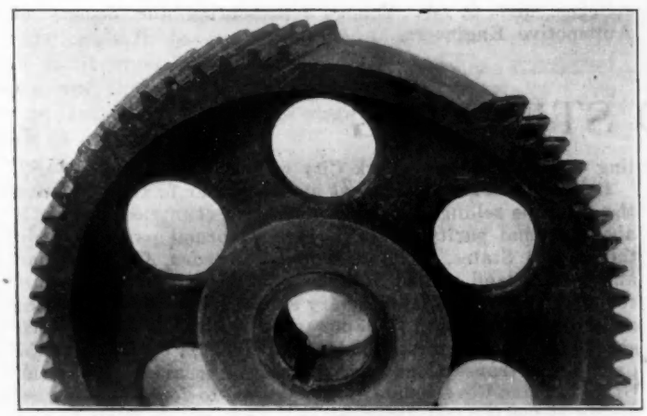


Fig. 2—This Camshaft Gear Shows a Very Uneven Wear on the Face of the Teeth After Running 10,000 Miles

heavy transmission oil in a closed gear-case. At the time that change was made it was commended almost unanimously by dealers and owners as a step ahead. However, a year later, when the cars using that system had been driven long enough to permit making com-

[1] M.S.A.E.—Chief engineer, Dort Motor Car Co., Flint, Mich.

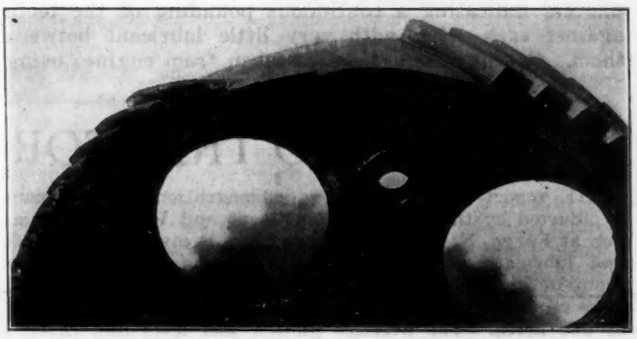


Fig. 3—A Camshaft Gear That Was Run 17,000 Miles with Heavy Oil as a Lubricant Showed Much Less Wear Than the Gear Illustrated in Fig. 2

parison with the older cars using the heavy-oil lubrication for the timing-gears, dealers complained that the new engines were noisier than the old ones, and that complaint has been chronic since, growing steadily as the quality of gasoline kept declining. As I analyzed the complaint, the cause of the noise was the excessive wear

Fig. 4—A Heavy Oil That Was Entirely Separate from the Crankcase Oil Was Used to Lubricate This Crankshaft Gear and the Backlash After Running 17,000 Miles Was Only 0.002 In.

of the gears and a rough condition of the tooth face. The cause of the wear is the poor lubrication received by the gears. The cause of the poor lubrication is easily traced to the use of oil with little lubricating value left. It is well known that all our present engines show a decided dilution of the crankcase oil, in daily use. This dilution is more pronounced in the high-speed types of engine than in the medium-speed types, but is present in all engines. It is more noticeable in cold than in warm weather, due to the longer time necessary to warm up the engine in winter. Such diluted engine oil is very thin and dirty and has very poor properties as a lubricant for the timing-gears.

I measured the wear of the set of timing-gears illustrated in Figs. 1 and 2, which were taken from a four-cylinder engine using crankcase lubrication that had run 10,000 miles, and found that the back-lash of the gears, which was originally 0.002 in., had increased to 0.018 in. On a four-cylinder engine of a different make the back-lash had increased from 0.002 to 0.016 in. in 8000 miles. The wear of the face of the teeth was very uneven, indicating a continuous pounding of the teeth against each other with very little lubricant between them. On the contrary, gears taken from engines using the heavy-oil lubrication in the gear-case show very little wear and a smooth tooth face, and the engines run much more quietly. This set of gears is shown in Figs. 3 and 4 and the difference in the amount of wear can be readily seen by comparing these illustrations with Figs. 1 and 2. The back-lash in this instance is only 0.002 in.

The conclusions to be drawn seem to be that an independent system of lubrication of the timing gears with clean and preferably heavy oil, with no connection whatever with the crankcase oil, is far better than the present system of using the crankcase oil.

FARGO TRACTOR DEMONSTRATION

THE report of the farming demonstration recently conducted by the National Implement and Vehicle Association at Fargo, N. D., is of interest since it gives average fuel and lubricating-oil consumption in terms of acres for a group of 36 tractors of various types and sizes. The tractors were required to plow, prepare the seed-bed and seed a total of 360 acres. The average plowed was level and covered knee-high with weeds, the soil being black gumbo.

TABLE 1—GENERAL AVERAGES OF ALL TRACTORS

Operation	Plowing	Preparing and Seeding
Kerosene Tractors		
Gasoline Consumption per Acre, gal.	0.120	0.094
Kerosene Consumption per Acre, gal.	3.010	1.250
Lubricating Oil Used per Acre, gal.	0.110	0.040
Man-hr. per Acre	0.940	0.418
Gasoline Tractors		
Fuel Consumption per Acre, gal.	2.770	1.280
Lubricating Oil Used per Acre, gal.	0.050	0.030
Man-hr. per Acre	0.950	0.430

The general averages of all tractors qualifying in the demonstration are summarized in Table 1.

TABLE 2—TRACTORS WITH CHEAPER FUEL

Operation	Plowing	Preparing and Seeding
Gasoline Consumption per Acre, gal	0.102	0.105
Kerosene Consumption per Acre, gal.	2.870	1.160
Lubricating Oil Used per Acre, gal.	0.095	0.040
Man-hr. per Acre	0.950	0.420

Other averages were secured for tractors whose fuel costs were lower than the general average of those given in Table 1. These are included in Table 2.

The six tractors whose fuel costs were lowest, based on Fargo prices of 11.8 cents per gal. for kerosene and 23.1 cents per gal. for gasoline, gave the results presented in Table 3.

TABLE 3—TRACTORS WITH MINIMUM FUEL COST

Operation	Plowing	Preparing and Seeding
Gasoline Consumption per Acre, gal.	0.041	0.034
Kerosene Consumption per Acre, gal.	2.510	1.010
Lubricating Oil Used per Acre, gal.	0.080	0.020
Man-hr. per Acre	0.840	0.320

HORSE RESULTS

Five horse outfits competed with each other and independently of the tractors in the work of plowing, preparing the seed-bed and seeding 10-acre plots. The average feed costs for horses are given in Table 4.

TABLE 4—FEED COST FOR HORSES

Hay Used per Outfit, lb.	352.00
Oats Used per Outfit, bu.	13.85
Man-hr. per Acre Plowed	2.64
Man-hr. per Acre Prepared and Seeded	1.43

These results are based on written reports of observers who checked the work of each horse and tractor outfit, and were compiled by the Supervising Observers Committee consisting of H. H. Bates, chairman; E. A. White, president of the American Society of Agricultural Engineers; Prof. J. B. Davidson, Iowa State College, representing agricultural colleges, and O. W. Young, representing the Society of Automotive Engineers.

THE POUND STERLING

OVER the greater part of the world the rate of exchange on London normally is an accurate indication of the trade balance. The price of the pound at New York City is a way of expressing the value of American goods that the pound will buy there. Normally it will buy $4.86 worth but when the British demand for American goods is urgent, competitive bidding by British merchants or bankers inclines them to pay more and more for the goods, in other words to take less and less for their pound.

In periods of normal trade movement the price of the pound at New York City rarely moved outside the limits of $4.84 to $4.89½. At $4.84 or below, it was cheaper for the Briton to buy our goods with gold than with a pound's worth of goods; therefore at $4.84 gold would leave London for New York City. At $4.89½ or higher, on the other hand, the Briton would not take our goods; they were too high; he would send a pound's worth of his own goods and get $4.89½ of our gold; with that $4.89½ worth of gold the Briton could buy more goods elsewhere than he could get from us. Therefore at $4.89½ or higher gold, not goods, would leave New York City for London. So smoothly did these processes work that for more than 30 years before the war the highest price of sterling exchange at New York City was $4.91, the lowest $4.82.

It is a remarkable fact that at most other financial centers the pound is selling at a premium. In 28 countries sterling is above normal parity in 20 and below normal parity only in the United States, Holland, Canada, Sweden, China, Japan and Switzerland and at Hongkong. The reason for the discount at New York City is a very simple one. The war created an enormous demand for our goods, which were shipped abroad to a much greater value than foreign countries could pay. These transactions were financed in a large part by the United States Government, which loaned to foreign countries nearly 10,000,000,000 American dollars to enable them to pay for these goods. As long as the American goods were paid for by these American dollars, the price of the pound at New York City was not controlled by the value of the goods moving from our shores, and it was possible for government control to "peg" it at $4.78. Shortly after the armistice this government support was withdrawn and the pound once more stood upon a competitive basis. All other foreign currencies are selling at a discount in New York City; not one of them is at par.—A. W. Kimber in *Michigan Manufacturer and Financial Record.*

Comparison of European and American Automobile Practice

By Maurice Olley[1]

New England Section Paper

THIS paper is presented more as a record of impressions than an accumulation of facts and figures. It will be confined to passenger cars and as far as European practice is concerned, to England and France, which can be taken, I think, as representative of the two schools of automobile development in Europe, France representing Continental practice, while English motoring has developed along lines to suit its own peculiar conditions.

Perhaps it would be well, as a beginning, to look at the difference between the automobile industry in Europe and in America, and then consider briefly the reasons for the difference. The American industry is turning out large quantities of cars on a purely commercial basis. Its mind is concentrated on the ultimate consumer, who it appears to believe rules it completely. The French and English builders are not in this position to the same extent. They do not produce cars in such large quantities, but each supplies a strictly limited field with a specialized product of some individuality. The profits of past years have not been entirely reinvested in enormous increases of plant and equipment and therefore they are at no time as securely tied to the market as their American brethren. The only quality that their products must possess to sell is that they shall transport passengers on the road with some degree of reliability and considerable speed. Beyond this requirement, there is absolute freedom. Here, on the other hand, every builder of vehicles, except motorcycles, must make something that has all the qualities of the traditional automobile; it must have an engine of at least four cylinders, almost necessarily water-cooled, with the conventional arrangement of accessories under the hood, a clutch and three-speed gearbox and the customary propeller-shaft to the differential and live axle. Of course, it must have four wheels and a top or covered body, and the wheels even must be 56 in. apart, no more or no less, a truly crippling state of affairs as far as design is concerned.

Differences in American and European Conditions

In connection with the reasons for the differences of the industry and design of cars here and in Europe, in the first place motoring here is transportation, pure and simple. It is rapidly becoming the most important system of transportation in the country. In Europe, leaving aside the recent vast increase in trucking in England, the automobile is not transportation but adventure. A man mounts his 3-hp. motorcycle in England with the feeling of a knight-errant. Here he jumps into his four-door sedan as one boards a street car. This one fact is of the utmost importance in automobile design. One explanation of it might be that there are about 10 or 15 times as many cars here per capita. I think this may be an effect rather than a cause, the car being so essential to transportation here that a vast number were produced, while the car was so unessential in Europe that it remained a rarity.

Probably the great reason for motoring being a commonplace here is the higher standard of living that brings a car within the reach of almost everyone, whereas in Europe it is still almost a luxury. Again, in Europe the better roads, the more attractive and historical countryside and the more merciful climate enhance the pleasure of motoring. At the same time the commuting difficulties that curse the wage-earner in this country, for some reason do not exist in Europe. All these causes contribute toward rendering the car in Europe a vehicle of considerable romance, not merely a daily drudge or a common household appliance.

A very important factor in the European automobile world is the cost of owning a car. The first cost, as compared with that of the United States, is difficult to determine, because of the reduced value of money and the difficulty of assessing the true value of cars. It will be best probably to take prewar money equivalents, since the value of money decreased about equally in Europe and here during the war. It appears to be approximately true to say that a car will cost twice as much in England as in the United States in proportion to living standards, and in France almost twice as much as in England.

In England gasoline costs about 80 cents per imperial gal. (65 cents per United States gal.) and in France, from 12 to 15 francs for 5 litres ($2 to $2.50 per United States gal.) Tire prices have apparently declined in England even more than in the United States. In prewar days tires there were about twice as expensive there as here. Furthermore, whereas American makers understate the actual size of their tires, the European tires were far below their stated size. Perhaps, as a consequence of this, the European tires will not generally give anything like as good mileage as American tires of equivalent rating. As an example, the 895 x 150 mm. European tire, which should be about 36 x 6 in., is actually the close equivalent of the American 33 x 5 in. as regards both size and wearing qualities. Taxation of cars is heavy in Europe, particularly in England where the tax is now £1 per hp. per year, the horsepower being calculated from the cylinder diameter exactly as in America.

The fierce competition of the motorcycle in England at least, which is continually developing to get the small-car trade, is the third condition affecting the industry and design. The motorcycle is favored by the higher cost of gasoline, tires and taxation, the later average age of marriage, the habit of renting houses rather than buying them, with a consequent shortage of garage space, and better roads and weather conditions. I imagine that in England there are at least two motorcycles to one car. There are 7 firms building motorcycles in the United States as compared with 50 in England.

The automobile industry is limited by the lower standards of living, by lower wages and also probably by a higher standard of thrift. The limitation of the indus-

[1]M. S. A. E.—Engineer, Rolls-Royce of America, Springfield, Mass.

try has reacted upon itself in enhancing the cost of cars. It remains to be seen whether Ford and the other American invaders can break down this obstacle to development. Another limiting factor is the distinct prejudice in the minds of many Englishmen against motorcars because they are an offense against the doctrine of "regular exercise." Many well-to-do city men living in London suburbs do not own cars to this day because the week-end is devoted to exercise of one sort or another, cycling, walking, tennis or cricket, and a car might break down these regular habits.

The design of cars is, of course, affected directly by climatic conditions, the open car being the popular model all over western Europe, and the top, or cape-cart hood, as it is still called, being an accessory, for use only in severe weather. Road differences affect design differently in England and France, the national highroads of the latter country, and perhaps the racial peculiarities of the inhabitants, making speed the one essential. Design in England is affected greatly by the essential democracy of its inhabitants or perhaps by the fact that there the car is not the standard of the man. Here a man will buy a car of cost proportioned accurately to his income or his pretensions. There a cabinet minister or railroad president will own a Ford sedan or take pride in the possession of a miniature vehicle peculiar to the country called a "light car" or voiturette and resembling a traveling bathtub. His social status is not governed by the car he drives, or by his income, but rather by the particular accent with which he speaks the English language.

Summarizing the conditions then, they are

(1) Spirit of adventure
(2) Cost
(3) Motorcycle
(4) Limited size of the industry
(5) Climate
(6) Roads
(7) Lack of definite money standards

Surveying these governing conditions casually, one can trace the effects with reasonable accuracy. The European motorist demands less convenience than the American. As an example, whereas the latter insists upon electric starting and lighting, even on a Ford car or a motorcycle, many European smallcar owners are content with electric light only, retaining hand-starting; and many small cars, and nearly all motorcycles, retain the old-fashioned gas lamp. The American user demands that the car give useful service with the minimum of skill in handling, whereas the English, and still more the French, owner delights in a car which will give maximum results in the hands of a skilled driver.

Cost affects the Continent and England differently. On the Continent, though many excellent small cars are being produced, the best efforts of the trade seem to be mainly directed to the larger cars, and the automobile trade appears to have made up its mind to cater to the rich principally. In England, on the contrary, the middle class is having its demands met by the cars that I have called traveling bathtubs. These little cars have been produced continuously in England since the earliest days but have always either perished, because their cost was out of proportion to their performance, or have gradually developed into larger and more pretentious vehicles. The small car appears to have come in with a rush in England and it seems that it will be the quantity-production car of the future in that and perhaps other countries. These miniature vehicles, complete in every essential, are excellent machines, from every point of view, for use where roads are good.

Motorcycles and Small Cars

The motorcycle is becoming an institution in England and is used by old and young, and by both sexes almost equally. On English roads and in English weather it is the perfection of motoring as distinct from mere luxurious riding. The machine weighs only 150 lb., is no bigger than an ordinary bicycle, travels 100 miles on a gallon of gasoline, and yet is capable of an average speed of 30 m.p.h. and a maximum of 60 m.p.h. It can never lose its place in the affection of the British motorists, 80 per cent of whom have probably served their apprenticeship on motorcycles. It is a fine training for driving a car.

There is no hard-and-fast line of demarcation between motorcycles and cars in England, except in the matter of number of wheels. All vehicles of four wheels, however arranged, are classed as cars and taxed at the rate of £1 per hp., while all vehicles having two or three wheels are motorcycles in the official eye and are taxed independently of horsepower at a flat rate of £4 per year with three wheels and £3 per year with two wheels. Accordingly, there has been a development away from the traditional motorcycle and side-car combination to a machine which is in all respects a small car except that it drives to a single rear wheel instead of the customary two-wheeled real axle. These vehicles, which cost not more than £300, are now of very good mechanical construction, and are entirely safe because they are hung low. They are fast and efficient, making 50 miles per gal. at speeds up to 45 m.p.h. The gradual development of the three-wheeled type would have been a severe blow to the carbuilders had they not met it with small cars of even greater mechanical merit which can carry two or four persons in comfort at high speed, with a rating not exceeding 12 hp. The upward movement of the motorcycle and the downward movement of the car have determined the typical present-day British car-type, coupled, of course, with the heavy burden of taxation and the high cost of fuel.

The limited size of the industry and of the individual manufacturers in Europe makes for higher cost, but for a more painstaking treatment of both the initial design and the finished article. It makes for a car of more individuality, a greater distinctiveness in each maker's designs and a greater receptiveness to designs that are highly unconventional. It is well known that where the output is restricted the product is likely to and may safely have more individuality than where the output is great. In other words, the design of the average European car is largely controlled by the engineering department, whereas the design of the American automobile is principally controlled by the buying public through the sales organization. In the main this seems to be the explanation of the great similarity of American cars as compared with European. Consequently minor points of individuality which would pass unnoticed in the description of a European car are emphasized in the American advertising, from which the public would assume that there were many points of design differing radically from those of other cars.

The climate is chiefly felt in body design. There is a positive prejudice against permanently covered cars, except in the most luxurious types. The top is still merely an emergency affair of waterproof canvas which is put up only for severe rainstorms. Wings and skirting panels are less complete than in America, and the protection

against mud and water is not nearly so advanced. Generally, the weather-proofness of the European cars is less perfect than that of the American vehicles.

In the mechanism of the car, the principal effect is that the control of the water temperature has not attracted so much attention as in the United States, and less care is taken on the average European car to insure an effortless start in cold weather. When night temperatures very seldom fall below 27 deg. fahr., a car designed solely for use in England and employing a fuel far superior to American gasoline need have little provision for forced vaporization. The Rolls-Royce practice of fitting a vaporizing primer and regulatable jets is very exceptional in England and entirely due to its cosmopolitan use.

Road Conditions

In England, even after years of neglect, the roads are excellent. The moist temperate climate keeps a water-bound macadam road in perfect condition almost forever without repair, as long as the traffic is not too heavy. However, the grades are heavy, the roads have simply grown rather than been planned, and hence there are few straight stretches and few easy hills. Most of the roads are narrow, the old coaching turnpike and the occasional vestiges of the old Roman "streets" being the only exceptions. Because of the hedgerows, blind corners and hidden crossroads are the rule rather than the exception and as a result handiness is essential. Cars must run well in high gear at all reasonable speeds and on all ordinary grades, and the brakes must be ready at instant call.

In France there are three sorts of road: the national highways, which are perfect motoring roads in every sense of the term; the secondary roads, which are the opposite, and the cobbles in the towns and villages, which are atrocious. The result is seen in the French cars where speed for the national highways is the first consideration. Roaring, noisy engines that will make 4000 r.p.m. without flinching for hours are demanded and the carbureters, which may or may not give flexibility, must be of the "straight through" type offering no obstruction to the inlet gas. Brakes, often on all four wheels, which will pull up a speeding car in a minimum distance are a prime requisite. For the by-roads and city streets, with unflexible carbureters, there must be four speeds, a powerful clutch-brake, an easy gearshift lever and plenty of slack in the transmission gears, so that the lever can be crashed over, up or down, at all speeds, without care or effort. There must be stiff springs and a sturdy framework, both for high speed and for city cobblestones.

The average Continental car on English byways is uncomfortable to drive and ride in, being rough and noisy and calling for continual gear-changing. On Continental roads it is in its element and shows to advantage if one is a courageous speed-hound.

American road conditions, now happily improving, have called for a car which can "go anywhere in high." Hence the low axle-ratios, large engines, small high-velocity induction systems, and other features which cause the typical American car to "waste its sweetness on the desert air" at all speeds above 25 m.p.h. The American car is the most convenient vehicle in the world to start and drive. It is best able to get any place whether there is a road or not and is the paradise of the lazy driver. It is year-round transportation with the minimum of grief, but it is not a speed monster. It is not pleasant to steer, with certain exceptions, and its brakes are deplorable.

Car Idiosyncracies

If an American has a car it must be a real car or at least look like one, and be of such a size that the human figure does not noticeably overlap the edges. Builders of the smaller cars, in the illustrations of their advertising matter, fill their cars with pigmies to enhance the impression of reality. To agree with the illustrations of my own car, I should not be more than 4½ ft. tall. The American buying public is assumed to have formed its standards. It expects, or so the builders assume, the same main features in a $1,000 as in an $8,000 car. In France and on the Continent as a whole the full-fledged car is generally for the rich and as such is complete and rather conventional and also distinctly expensive. There have always been in France voiturettes with one or more cylinders, but they have never been regarded very seriously and actually do not call for a full driver's license for permission to operate. In England there are no accepted standards of design. The only two standards of practice are speed and economy. Until recently there were many single-cylinder cars. Now these have disappeared, but an engine can have two, three, four five, six or eight cylinders; it can be air or water-cooled, horizontal, vertical, Vee or radial. The transmission can provide two, three or four speeds, or, as in a number of small cars, drive by friction discs and gears, or chains to the rear axle. Chain, propeller-shaft or V-belt, Hotchkiss drive or torque-tube, differential gear or none, rear axle or single wheel, all are acceptable to the buying public. The actual size and shape of the cars vary enormously. The three-wheeled vehicles generally have the single wheel behind, but at least one has two wheels on one side and one on the other. The track width of four-wheeled cars varies from 42 to 58 in. and the wheelbase from 80 to 150 in. The tire sizes on cars vary from 27 x 2½ to 35 x 5 in., and wheels may be wood, steel-spoked, disc or wire, the last being in the majority. Starting may be electrical or unassisted. Lighting is by electricity or gas. The ignition, however, is almost universally by magneto, but the battery is slowly gaining.

External appearance is uncontrolled and varies from the extremely dignified to the extremely weird, and from the utmost symmetry to an indescribable lopsidedness. Among the miniature cars, some most beautiful proportions are to be found, while many bodies fitted on large cars would attract jeering crowds in the United States. The reverse is equally true. England and Europe generally demand the full run of the spectroscope as regards color and trespass over the edges. To European eyes all American cars are black. Bear in mind that anyone may ride in the most peculiar or tiniest of these cars without loss of dignity, and it will be possible to see how free and untrammelled the scope of automobile design is in England.

Selling Conditions in Europe

Perhaps what I have already said will serve to show the conditions that American cars have to meet in Europe. American cars have sold and are still selling in Europe in large numbers, because they have a great reputation for reliability, and they can always be bought from stock, but they do not show to such a great advantage in Europe as in America. The reason for this is that their engines are, from the European point of view, too big for the performance obtained from the car. In other words, they consume too much gas. Table 1, giving the average specifications, will illustrate this.

TABLE 1—AVERAGE SPECIFICATIONS OF CARS

	American	English	Continental
Number of cylinders	6	4	4
Power according to National Automobile Chamber of Commerce Rating, hp.	26.00	13.80	15.50
Bore of Cylinder, in.	3.40	2.95	3.10
Stroke, in.	5.00	4.75	5.10
Stroke-Bore Ratio	1.45	1.60	1.65
Average Gage, in.	56.00	51.00	53.00
Minimum Gage, in.	56.00	42.00	40.00
Maximum Gage, in.	56.00	58.00	56.00
Average Wheelbase, in.	122.00	115.00	122.00
Minimum Wheelbase, in.	....	88.00	86.00
Maximum Wheelbase, in.	....	150.00	146.00
Axle Ratio, in.	4.50	4.15	....
Number of passengers	6	3	....
Weight of Chassis, lb.	....	1,800	....
Approximate Weight of Complete Car, lb.	3,000	2,300[2]	....
Price	$2,794	£610	....

[2] Many English cars completely equipped weigh from 1500 to 1700 lb.

In France a number of cars are developing on American lines. Unit construction, battery ignition, smooth external appearance, detachable cylinder-heads, left-hand steering and a host of detail fittings are making them appear more and more like American cars. They differ, in having greater speed and less high-gear flexibility, but better brakes. I cannot find the average price of Franch cars but imagine that the rate of exchange, import duty, etc., make competition from this side very difficult.

The American car probably is at a disadvantage in its quality of finish and the detail design of its mechanical parts, which have always looked rough-and-ready to the European eye. The lower maximum speed would count against it. Since on the Continent cars are only run by people of some wealth, the tax and fuel consumption of American cars are not insuperable objections. To judge by prewar experience, the smaller Continental cars are lacking in completeness, convenience and mechanical perfection. For example, the Continental designer has always appeared to lose patience when he gets to such details as the controls; accelerator connections, for example, are likely to consist of the fewest possible pieces of bent wire and to be proportionately unreliable.

The more interesting conditions exist in England. Here there has always been an admiration of the low-priced American cars, and from the first days builders have been striving to evolve a low-priced car for the English market. The "£100 car" has become almost a slogan. The failure to produce a really low-priced car has been largely due to the fact that English builders have not realized that a really good inexpensive car can be secured only by quantity production, and that it is a matter of capital and tools rather than design. The attempts at low prices have failed because they have "cut corners" in design and produced something which was either not safe or so unlike a real car as to be unacceptable even to the catholic taste of the country. Now with the heavy tax on horsepower and expensive gasoline the conditions have changed and the English builder should be able to meet American competition with a car that is, perhaps, a little more expensive than the imported vehicles in first cost, but much more economical to run, smaller, handier, equipped with better brakes, has a better external appearance and is generally more suitable to the local conditions. In this respect it is interesting to consider Table 2, taken from *Motor* (London), Jan. 12, 1921.

The ordinary American car even of the smallest class would be at least as expensive to run in England as the most expensive type quoted. It seems to me that England is on the point of solving its transportation problems in an effective manner. In view of the fuel consumption given, England apparently is achieving real fuel economy, and it becomes a question whether this country might not attempt to develop on similar lines. Surely, as a first step to fuel economy, it would be logical to reduce the horsepower of American cars by 50 or at least 30 per cent, leaving the axle ratio unchanged or even raising it considerably, and gaining flexibility by a reduction in weight and improved carbureter design and also perhaps by four-speed gearboxes. The objection might be made that it would be necessary to shift from high speed more often, but the English light cars only have to shift the gears occasionally in ordinary running conditions to judge by the reports of trial runs, unless exceptional grades are met, and the grades in England are very much worse than here.

Objections to a gage less than the traditional 56 in. are often heard. The first is that the car rocks sideways more with a narrow than with a wider track. I think this is not so on road surfaces where reasonable speeds can be kept up. The 7-ft. gage railroads in England were proved to roll more than the 56½-in. gage, and narrow-gage railroads show good riding qualities. The same argument applies to narrow-gage cars on decent roads. The objection that the narrow cars will not fit the ruts made by other cars on dirt roads or snow works both ways, I think. Personally, on a light car, I prefer not to have both wheels in the ruts at the same time. In the same way street car lines are safer for a car whose gage does not fit them.

TABLE 2—COMPARISON OF CARS

Size and Type of Car	Four-Passenger 16 to 20 hp.	Four-Passenger Small Car	Two-Passenger Light Car	Four-Wheel Cyclecar	Three-Wheel Cyclecar
Weight, lb.	2,800 to 3,300	1,800	1,600	1,350	Under 800
Tax	$75 to $100	$50 to $70	$50	$50	$20
Fuel Consumption per Year, Imperial gal.	250	200	166	110	85
Miles per Gallon of Fuel	20	27	30	45	60
Cost of Fuel per Year	$220	$160	$145	$90	$74
Miles per Gallon of Oil	500	700	1,000	700	700
Cost of Oil per Year	$25	$17	$12	$17	$17
Cost of Tires per Year	$150	$90	$75	$60	$50
Total Annual Cost	$465	$317	$282	$222	$161
Annual Cost per Person[3]	$116	$80	$140	$110	$80

[3] Figures are based on the assumption that full use is made of the seats. Since the four-passenger cars can be assumed to carry not more than two persons on the average, it is safe to double the cost per passenger in the first two cases.

Road conditions are certainly bad in the United States as a whole, but are rapidly improving, and in the Eastern States are becoming similar to the English roads. I believe that a light car of European design would perform very well on the ordinary roads of Massachusetts. a narrow gage would certainly not be an unmixed blessing in winter with its heavy snowfalls, but I think that a small car with a low bottom gear, not too much forward weight and a really good control of the rear axle, would push its way through most obstacles, particularly if the road clearance were kept fairly high by sloping the transmission and using small rear-axle gears. Four speeds would be almost a necessity.

Comparison of General Design

Many European cars are built around the engine and in fact in some of them the designer's interest appears to have waned after the engine was completed. This was a real failing of many prewar cars. A real attempt to raise the mean effective pressure in European cars, by increased compression, inlet-valve opening and induction systems is noticed. The valve-in-head engine is coming in slowly and generally is equipped with a detachable head. In at least one case of a detachable head screwed plugs are still used over the valves. This seems good, since with the detachable head, although the operation of cleaning the cylinder is made easier, there is far greater difficulty in making a quick inspection of the cylinder and valves than with the older type of non-detachable head with screwed plugs over the valves. Also, it is more necessary to inspect the interior of the cylinder when a detachable head is used, because of the danger of internal water-leaks. With the ordinary type of detachable head, when once the head is removed and replaced, there is a constant fear as to what sort of joint has been made, and the only way to find out is to detach the head again, and so on ad infinitum.

In a large number of valve-in-head designs the camshaft is on top, following airplane engine practice. The contrary school is still vastly in the majority, proving by excellent examples that a well designed L-head engine can be as efficient and as free from detonation as the valve-in-head. The two-cylinder horizontal-opposed engine is gaining much favor for light cars, this being a development of motorcycle design. Air-cooling is considered only for small cars, probably because the danger of freezing up is practically not existent in Europe.

Magneto ignition still holds the field in Europe by an enormous majority, but certain makers have been tempted by the excellent American battery-ignition systems to abandon their former practice, probably as a matter of justified economy. On small cars without an engine-starter the magneto is almost universal and seems correct, since in this way the car can always get home, battery or no battery. As long as an engine is free enough to be started by hand on the magneto, there is a real advantage in having one, as least as a second string.

The battery-ignition wires and apparatus extend over half of the car and a number of things are likely to happen to the wires and terminals in inaccessible places which may take endless trouble to remedy. In magneto ignition the only wires are the high-tension leads to the plugs, failures of which affect one plug at a time and are easily traced, and one ground wire which is sometimes omitted on European cars. The last, if it breaks, will not stop the engine but will prevent stopping it. Hence the European faith in the magneto, which will take a lot of shaking.

Clutches are about evenly divided between the cone and the plate types in Europe, whereas in America the latter is in a large majority. Perhaps this is accounted for by the excellent cone-facing fabrics which one can obtain in Europe and by the cheapness of manufacturing a plate clutch from pressed steel in America. In this Country it is necessary to have a clutch that will slip longer without burning, because of snow, and the multiple design is good in this respect, of course, but not better than a cone clutch with heatproof facing, which is more likely to remain cool than a pack of discs.

Gearboxes have four speeds on 80 per cent of Continental cars and 50 per cent of English cars, including a large number of the small cars. The advantage of four speeds, particularly on the small cars, is evident and might be considered, one would think, for America, if the public could be educated to it. For small powers the extra weight of a four-speed box is not great, and the speeds are needed. With a decent clutch and carbureter the car should start on second speed and climb most hills on high and third speed, but the first speed is good for emergencies. Gearboxes are being combined more and more with the engine on Continental cars, particularly the small ones. In England, however, the majority of gearboxes, all cars considered, are still independent and fastened to the chassis behind the engine, 70 per cent being mounted in this way. On the Continent about 50 per cent are attached to the chassis and 50 per cent to the engine, and the latter method is on the increase.

Some of the English light cars using two-cylinder engines of the horizontal-opposed type combine the clutch casing and gearbox with the crank-chamber in a very neat form, so that the entire working mechanism of the car is accessible by merely raising the bonnet. Gleason bevel gears are coming into use to a great extent, and are displacing not only the straight bevel gear, but also the worm which before the war seemed to be gaining favor rapidly. The Gleason bevel is undoubtedly one of the biggest contributions to automobile design since the Bilgram bevel-gear planing-machine.

Springs are almost always half elliptic on the front axle. At the rear, there has been a landslide to the quarter elliptic and cantilever, which were fitted on 70 per cent of the cars shown at the recent Olympia exhibition. The half-elliptic springs, so popular here, are fitted on less than one-sixth of the European cars, if we can judge by the recent shows. Since the cantilever spring implies some sort of effective control of the rear axle, the movement in this direction seems to be good. The torque-tube, or other axle control scheme, seems too short in many European cars, to be really good. In most of them it would have been possible to lengthen it considerably, with advantages in riding qualities and in holding the road. Some of the European cars retain the fork joint at the head of the torque-tube without any provision for a side movement of the axle, but most builders seem to realize that this is wrong and use a spherical or other universal joint. Generally speaking the one or two torque-tube designs which have recently appeared in the United States are far better than the general run of the new European designs, as regards both mechanical design and appearance.

Several of the lighter English cars omit the differential altogether, and drive either one wheel or both wheels through a rigid axle shaft. This practice does not appear to ruin the tires on a car of 2000 lb. or less, and is worthy of consideration in the United States because of its great advantage in mud or snow. America has

better tires at a lower price than Europe, which is an additional reason why it should consider dropping the differential on small cars.

American design seems to be at a standstill as regards brakes and the European design is almost without exception better. The good point about the American design is that both brakes are generally on the rear wheels, but this is neutralized in most cases by the lack of an equalizing device. The bad points appear to be that the external brake, which is relied on to do the work, is in effect little more than the old-fashioned strap brake, tried and abandoned on bicycles. It is likely to grab, is only approximately balanced, is unequal in its application, springs considerably before it really gets hold, is exposed to all the winds that blow and yet will heat up almost immediately. On very few cars does it ever really come free. The internal or so-called emergency brake is generally no more than an enlarged piston-ring and is best disregarded. The smell of rubber and burnt string on any American highroad hill in the touring season is sufficient criticism of the local brake design, and the columns of the newspapers are its condemnation.

The means of applying the brakes too often consist of bent wire and other things that spring, so that the driver cannot tell the moment at which his brakes make contact and simply keeps on pressing with his foot, in the hope that something will happen soon. When it does, it often skids the wheels because the bands after slipping for a time have grabbed. Brake facings in America do not appear to be equal in wearing quality to those used in Europe. The use of rods to the rear axle, instead of steel strip or cable, leads to rattling and frequent breakage.

One would imagine that the double internal-expanding brake so often used in Europe would be cheaper to manufacture than the general form of American band-brake, since it consists of fewer parts and is a machine job from start to finish. It is better because it is weatherproof, will not run so hot, is more definite in its application, and is better balanced and more readily adjustable. The side-by-side variety implies a wide drum, but a new type which has appeared lately, consisting of a single, width drum with four internal shoes, each working on a quarter of the circumference, and controlled, one pair by the pedal and one pair by the lever, seems to solve the trouble. Pressed drums can be used, but should be flanged outward on the inner edge for stiffness and cooling, and should be bored or ground to run true. Improvements on the lines suggested would form a great step forward in American cars.

Much adverse criticism of American bodies has appeared recently in the English technical press, but an examination shows that it applies wholly to the open touring bodies, to which I imagine American builders have not given much attention lately. Recent American open bodies have aimed too much at sporting lines to be comfortable. They are not deep enough and the seating is too upright. I think the designs which are now critisized in Europe came originally from Europe in a number of cases. Europe has, however, reverted to deep comfortable open bodies, such as were standard in this country before the war, using them all the year round and therefore demanding the utmost of usefulness and comfort.

This Country undoubtedly leads by a very large margin in detail finish of closed bodies and in accessories, and I cannot help feeling in general lines also. The recent developments in quantity production of closed coach-built bodies form another notable advance for which the United States is responsible, and the quality of workmanship and material in these closed jobs seems to be at least as good as much of the exclusive coachwork of Europe.

America proved that the automobile is not the monopoly of the rich, and is now showing that true comfort in the automobile is equally available to the man in the street. In other words, what the public wants, it shall have. The quantity production of coach-built bodies is a great step in advance not only because of low price; by quantity production coach-building is lifted from an art to a mechanical science. It has been shown that timber can be worked accurately to make interchangeable parts and like metal is capable of proper heat treatment and that results can be guaranteed. The individual coach-built body is often a nuisance to the manufacturer of the chassis and the owner of the car, because it is found frequently that in some particular the body work clashes with the mechanism of the chassis, or vice versa. By the quantity production of bodies such interference can be rooted out in the first experimental sets, electric wiring can be standardized and a whole host of minor annoyances thus be avoided.

In Europe the open car will probably always hold the field because of the difference in climate. Without doubt any form of covering for European cars will have to be truly collapsible. Perhaps America will now show that a really convertible job can be produced in quantity, which will not rattle and can be thrown wide-open in the fine weather and covered again by two persons in 5 min. European and particuarly English closed-body designs appear to be going through a phase which one hopes will be temporary. The rear end of a number of English bodies resembles that of a sausage in general design. I refer to the excessively rounded designs that are so popular in England just now and appear so hideous to American eyes. In touring cars the European designs are almost uniformly good except that in some cases the desire for a disappearing hood has spoiled the lines of the car.

Sheet aluminum is used extensively in European body-work but the treatment is not as complete as in American bodies, and exposed wood joints are used in window-frames, which are likely to give trouble in the event of a change of climate. Aluminum roofs, used to obtain rounded designs previously mentioned, are not satisfactory in many instances as they tend to boom badly and they make the interior uncomfortably hot in summer weather.

Summary

As a summary, I wish to emphasize the following points:

(1) The use of cars is radically different on the two sides of the Atlantic, and selling points which are vital to the American public, such as engine-starters, transmission locks and service organizations, are of secondary importance in Europe

(2) The cost of running a car is greater in Europe and the roads are good; therefore cars are growing smaller, and it is the small car, above all things, which appeals to the general public, especially in England. If America wishes to hold a big trade in England, she must evolve small, fast, economical cars of the utmost refinement as regards mechanical parts

(3) American body-work, as known in Europe, is unsatisfactory. Actually American body-work, as a whole, is of a higher quality than the European.

It only remains for America to turn her attention again to producing comfortable touring bodies, for her to meet European requirements absolutely in this respect

(4) American brakes need an entire redesigning from the pedal or lever to the rear axle, if they are to meet European ideas. The idea of the hand-brake being an "emergency" brake must be eradicated. If it is to be used in an emergency only, the driver never accustoms himself to use it, and in an emergency it is never ready. It is immensely better to call it a hand-brake, make it adjustable for wear and build it for use. It only remains to train drivers to use it frequently on all long hills; it will then be used in emergency and may prevent a number of accidents

(5) Europe does not appear to know anything about detail design that is unknown in America. With the exception of the overhead camshaft engines, the small horizontal two-cylinder engines, the Argyll single-sleeve, the Ricardo trunk piston and one or two other items, every European design is reflected strongly in the United States

(6) If Amercia were to build light cars on European lines for export, I believe they would sell in large numbers in the eastern part of the United States, where road conditions are favorable to them. These cars must not be built for use in cities only however; they must have speed and capacity for touring equal to those of the largest cars built in this country

Except in the matter of their large size and horsepower the outlook for American cars all the world over appears to me to be particularly good, because the United States is now aiming at not only production but the production of high-quality designs. In recent American designs equal compression volumes are often insured by machining the heads; six-cylinder crankshafts have seven bearings and are finished all over in the circular grinding machine; pressure lubrication is used for all moving parts of the engine; and in all ways the highest practice is aimed at, combined with strictly mechanical methods. Other countries are trying to reduce costs while America, having done so, is trying to improve the quality without increasing the costs. It seems to me that it only remains for America to produce cars that are strictly suitable for European conditions, to gain a firm place in the esteem of European users. There is no doubt that having gained a place in the regard of the European public, American salesmanship and service organization will see that the place is retained.

THE DISCUSSION

V. A. NIELSEN:—Mr. Olley intimated that the English people do not look very much to service organizations. Will he please explain this point?

M. OLLEY:—They do appreciate service organizations, but they are not important as a selling point for a car. That was my meaning.

MR. NIELSEN:—Does this mean that service stations for taking care of the cars are not needed?

MR. OLLEY:—In this Country the service organization can be made a distinct selling point for a car. In England a better mail service is maintained, so that you can get anything over-night, and the fact that cars are not used daily makes the service organization of less relative value.

I. F. RICHARDSON:—Mr. Olley referred to the large number of Continental and English light cars. Does the same thing apply to the Italian field for the light car? And how is the Belgian field?

MR. OLLEY:—I can speak only of France and England from personal knowledge but I imagine that neither Italy nor France has a real field for the small car as it is distinctly an English product. This is a sweeping statement, because a number of small cars are being produced in both Italy and France. I think there are not many in Belgium. The Belgian roads are generally better than the French and the Italian roads as far as I have seen them. England is the most important market for the small car. For the Continent, generally, I think that it is only necessary to build a car that will travel fast, making its cylinder diameter as small as is feasible, for the sake of taxation, and having the induction pipe and the carbureter as "straight through" as possible.

A MEMBER:—How are the American motorcycles considered?

MR. OLLEY:—They are very popular in England and are going there as side-car machines. The average man who runs a motorcycle expects 100 miles per gal. of fuel. There is a general feeling that the heavy motorcycle is inconvenient and really an extravagance. The motorcycle is very often kept in the front passage, between the front door and the stairway, and it must be lifted up the stairs, which cannot be done very easily with heavy machines. The thing that has upheld the American motorcycles is their excellent rear springing, which commenced to count very heavily when certain roads began to be cut up by war traffic.

VICTOR W. DOW:—Is there a movement for standardization of sizes and dimensions?

MR. OLLEY:—The Institution of Automobile Engineers has done nothing of moment toward standardization. The very little amount of standardization that there is in England is regrettable. On passenger cars alone there are something like 35 different tire sizes between the dimensions of 27 and 35 in. In everything else, thread sizes, shapes of nuts, methods of locking nuts and in every particular there is a lack of standardization. However, as a measure of economy, standardization is coming in England. Whether it will come from France in metric sizes or from the United States, I do not know. The latter is making a great bid for the standards on tires, but France is making a big bid for the standardization of machine parts. The Metric Association in England is very strong, has gained membership rapidly and is trying to get everything reduced to metric sizes. All electrical work is, of course, in millimeters.

R. G. THOMPSON:—In general, what starting and lighting system is favored in England?

MR. OLLEY:—As far as I can see, in England the two-unit system is generally accepted. On all the big cars, an engine-starter is provided, but in the case of most of the small cars the starter is an extra. If a lady buys a small car, it is generally equipped with a starter. A man who has a small car will usually not bother to have a starter. He will most likely buy the car with a dynamo, and probably that is one governing factor in determining the use of the two-unit system. You must remember that the engines on the small 10-hp. cars can be turned over like a sewing machine. Bear in mind that the traffic conditions of the United States do not exist in England. If the engine stal's the driver can hop out and start it up again, and nobody will say anything or look nasty. Probably, if there are any traffic policemen around, one will come up and turn the starting crank, and in a country where it is possible to park at either side of the road

and in the middle, the mere delay of traffic is not regarded as an offense. It is probable that the very small cars will not be equipped with electric starters that would add perhaps 50 lb. to their weight; they are, of course, drawing the line very fine on weight. On the larger and also on the medium-weight cars, the starter is practically universal. The types of electrical starting and lighting schemes are not very many in England but they are developing very rapidly. A number of companies that engaged in the electrical business during the war are now turning their attention to starting apparatus. It is generally good, and finished better than the average American apparatus. It looks better on the outside but I think it could not do its work any better, because as far as my own experience is concerned, the average American electrical apparatus is practically perfect in service. Undoubtedly starting and lighting systems will be used universally on every car above 16 hp. and probably on 50 per cent of the smaller cars, but I think that for the sake of economy in the production of the car and in weight there will always remain a large number of very small cars in England and in France which will not be equipped with them, but they will all have a generator and electric lighting.

F. J. STONE:—Will you tell us something about the development of the commercial truck?

MR. OLLEY:—The most interesting feature of the truck in Europe is the very great development of the steam truck in England. It was developed for some War Office trials in 1898, and since that date it has not changed greatly in general form. Typically it consists of an old-fashioned traction engine, with the cylinders on top of the boiler, built into the forward end of a heavy wagon. The boiler is a miniature locomotive built for hand-firing with hard coal, and the engine an open-crank horizontal two-cylinder compound, with the crankshaft and flywheel at the rear end. The driving gear on the crankshaft drives a sliding-gear two-speed transmission, without the use of a friction clutch. It is, therefore, necessary to stop the engine to drop into the lower gear. From the transmission the drive goes by a long roller chain down one side of the car to a chain sprocket and differential on the rear axle. This is a live axle of apparently crude design, which, however, gives excellent service. Originally these trucks ran on steel tires at theoretical maximum speeds of 5 m.p.h. Now, however, they are almost always fitted with solid rubber or giant pneumatic tires, and make speeds up to 20 m.p.h. Since the start of the war trucks of this type have been built in England by probably a dozen firms, but they are not an innovation, having been in use in Lancashire for 20 years, transporting cotton from the port to the mills and back in very hilly country. They have gained a very secure place in England.

During the war the gasoline truck developed rapidly in England into a rather heavy monstrous but excellent machine, carrying generally about a 5-ton load. This type is now being produced in quantities in England. Another development is a self-feeding steam truck, looking more like the traditional automobile, using an ordinary hood with the boiler underneath.

Since the railroad strike in England long-distance trucking has been gaining enormously. During the strike all trucks were commandeered by the Government and the resultant improvement in the freight service, directly due to the railroad strike, was so remarkable that trucking is now on a very secure footing in England and the railroads on a correspondingly insecure foundation.

A MEMBER:—During the war a large number of the passenger cars were run with gas bags. Have those been abandoned?

MR. OLLEY:—That was artificial gas. Those have all been abandoned. I think they are not even permitted because of the danger of explosion, although the economy was remarkable, of course, as the gas cost only about 3½ shillings per 1000 cu. ft.; the cost of running was only about half the cost with gasoline.

A MEMBER:—What progress in the use of benzol is being made in England?

MR. OLLEY:—Benzol is accepted in England, universally, I believe, and it is preferred in France. Before the war benzol was being pushed by one or two of the automobile papers in England with the idea of breaking the grip of the gasoline trust. Mr. Royce used a large quantity of benzol in the south of France. We used it straight and also mixed with gasoline. Almost everybody was using it or trying it. Some people got foul engines, most of them got foul exhausts, and there was considerable disappointment. We put in a special float, I think that was all, to allow for the heavier liquid, and used it straight on the car in the south of France, for many months, with excellent results. The present position of benzol in England appears to be good. From what I can gather a large number of cars are running on a mixture of half gasoline and half benzol. Whether benzol will continue, I do not know, but at present it is an accepted factor, and I gather that most people are using it. In England we are providing for its use by making benzol floats and are already recommending customers to use a mixture, and in every way it is coming to be regarded as a standard. On big airplane engines it is considered necessary to use at least 30 per cent benzol to prevent detonation, and it is thought that by using a mixed fuel a bigger cylinder diameter can be utilized than with straight gasoline. The other development in Europe is alcohol, which is looked upon there as the probable final development of internal-combustion engine fuel. It is realized that oil will not last forever, and, as regards Europe, it is very difficult to procure. England, I believe, wishes to develop large tracts of land in Africa for producing alcohol. It has realized that benzol can be produced only in a relatively small quantity and will not replace the demand for gasoline, even as it exists at present. If alcohol can be produced and be made non-intoxicating, there is no doubt that it will be the fuel, probably in five years or possibly ten.

MR. NIELSEN:—Does benzol cause any deposit?

MR. OLLEY:—It probably does form a little more carbon than gasoline, but inasmuch as a large proportion perhaps of the carbon in the cylinder is road-dust, that does not make a very big difference. It was feared that some corrosive acid from the benzol might attack a steel cylinder, but apparently this is not so. I do not know whether it attacks aluminum.

E. A. COUSINS:—Mr. Olley, in referring to battery ignition, seemed to infer that the failure to be expected is in the wiring. In his opinion, is American wiring practice superior to that in England and in France?

MR. OLLEY:—I think that American wiring practice is very good. I do not know that I can say that England's trouble with battery ignition is due to failure of wiring, because few European battery-ignition systems have been marketed until lately, and, as far as I know, there have been no failures. All I meant to imply is that the European builder, regarding the simplicity of the one scheme, as compared with the complexity of the other,

has theorized and said that the magneto is practical and simple and that therefore he will stick to it. The consideration that the magneto does, to a certain extent, eliminate the necessity of providing an automatic advance, has led to the adherence to the magneto. Even in the case of motorcycles, where a large amount of hand adjustment is to be expected, the necessity of watching the ignition advance has led to a very great prejudice in favor of the magneto.

MR. COUSINS: — I have understood that tungsten breaker-contacts corrode rapidly in England.

MR. OLLEY:—We have been trying tungsten contacts and found that they corrode. I do not know whether that is due to the climate. I imagine that the climate might make a difference. Platinum contacts are still the standard in England. If tungsten contacts are found generally to give more trouble in England than they do here, we should be interested to know about it, because we are interested in any development in the use of tungsten or any other of the possible alloys. We are constantly in touch with and trying out all of those things, but at present we have not found anything to compare with platinum.

INTERNATIONAL COMMERCE

IN 1818, the entire volume of international commerce was only $2,000,000,000. In other words, after countless milleniums of life upon our globe, men had been able to produce only that relatively modest volume of world-exchange. And, for several decades thereafter, increase was not portentously rapid. In 1850, the volume of world-trade had grown to only $4,000,000,000. Between 1850 and 1900, world-trade increased five-fold to $20,000,000,000. This increase was astounding enough, but it was nothing compared with what was to follow. For the first decade of the twentieth century witnessed an absolutely unprecedented outburst of economic activity which, by 1913, carried the volume of world-trade to $40,000,000,000, an increase in 13 years as great as the hitherto unprecedented growth of the preceding half century. Not even the war sufficed to stop the momentum of the movement, for, at the close of 1918, the volume of world-trade had reached $50,000,000,000, albeit this was measured in the inflated currency of the present day. Such are the figures; $50,000,000,000 in 1918 as against $2,000,000,000 in 1818. Is it any wonder that the continent that was the motivator, nucleus and chief beneficiary of this twenty-five fold increase in international trade should have been able to support a three-fold increase in population?

The agencies making all this possible were, of course, improved transportation and communication. A century ago such matters had not advanced radically since the Christian era. In 1818, there was not a single ocean-going steamship, not a mile of railroad, not a foot of telegraph wire or ocean cable. As for electric traction, motor trucks, airplanes, telephones and wireless telegraphy; these are all the product of our own generation. In 1914, the world's steam shipping aggregated fully 30,000,000 tons, while the world's railroads totalled 725,000 miles, more than three times the distance from the earth to the moon.

These revolutionary developments in world-trade brought certain inevitable consequences in their train, the most outstanding of which was the economic integration of the planet. However profound existing political cleavages, mankind was being rapidly welded into an economic whole. And, having been thus integrated, the entire world came under the influence of that primal law of modern economic life, the division of labor. The same fiat that apportions the labor of 1000 men to the making of a single machine, each man devoting himself to his minute but indispensable part, began sorting out the various regions of the earth, assigning to the different areas and their peoples those activities for which they were best fitted, and through specialization upon which they could best contribute to the maximum efficiency of world production and exchange. And in this process Europe was assigned a preeminently industrial role. Of course, this could not apply strictly to so vast and varied an area as an entire continent, many European regions, in fact, remaining predominantly rural. Nevertheless, taking Europe as a whole, we may say that the tendency was all away from agriculture and toward urbanization and industrial life. But since Europe had thus become the chief workshop of the world, the other quarters of the globe took on the correlative function of sending to Europe, in exchange for its finished products, foodstuffs to feed its workers and raw materials to feed its machines.—Lothrop Stoddard in *World's Work*.

SOCIETY LIBRARY

A SMALL library is maintained in the Members' Room at the Society offices in New York City. It is planned to keep on the shelves the principal engineering and technical books on automotive vehicle design and closely related subjects. This will provide the members with a compact library where they can make a concentrated study of automotive engineering problems. New and authentic automotive engineering volumes will be added to the collection from time to time and a complete file of Government and research organization bulletins covering subjects of interest to automotive engineers will be available for consultation.

A set of the German Technische Berichte has been courteously contributed by the National Advisory Committee for Aeronautics. These consist of separate technical memoranda issued, as confidential material during the course of the Great War, by the Aeronautical Supply Department of the German Air Force. The reports contain practically all of the official German aeronautical information recently compiled from the research conducted during this period, covering a wide range of subjects, such as propeller study, methods of calculating aircraft performance, analysis of engine tests, design of airplane engines and authentic wind-tunnel tests of approximately 350 wing sections. This material is of course all in the original German. Any member interested in a particular report can secure photostats of it and it is generally an easy matter to have translations made.

Suggestions from members as to books that are of great value to the automotive engineering fraternity will be welcome and receive due consideration. It is of course not intended to attempt to duplicate in any way the magnificent Engineering Societies Library that is housed in the same building in which the Society offices are located. The privileges of this splendid institution also are of course available to the members of the Society.

Current Standardization Work

A MEETING of the Iron and Steel Division was held in the rooms of the Old Colony Club at the Hotel Iroquois, Buffalo, on July 25. The principal work accomplished was the reviewing of the draft of the Steel Specifications and the Notes and Instructions referring to their chemical and physical properties and applications now printed on pages D1 to D44 inclusive of the S. A. E. HANDBOOK, this draft having been revised at the June 20 meeting of the Division. It is the purpose to make the specifications and notes and instructions a reliable guide to the best current metallurgical practice. The data will, like those of similar nature in the past, be of the greatest value to automotive engineers specifying the application of ferrous materials.

CAST-IRON VALVE-HEADS

At the meeting of the Iron and Steel Division members held on June 20 a report on the feasibility of adopting a specification for cast-iron valve-heads was submitted by C. N. Dawe. This report, given below substantially in full, recommending that the subject be tabled indefinitely, was approved by the Division.

Apparently a soft gray iron is in every way satisfactory for valve-heads, although the production of suitable castings is not a matter of chemical composition alone, but largely a matter of foundry practice. If a chemical composition were specified, the recommendation would have to specify also the time and the temperature of pouring, the number of heads to be cast at one time and whether they should be cast "in series or in parallel." All of these points affect the final product.

This is true of not only valve-heads but of any cast-iron part on a passenger car. There is, of course, the distinction between hard iron made partly of steel scrap and real soft gray iron, but the classification is too general to be called a specification.

In regard to the hardness of valve-heads it seems to be the consensus of opinion that this is the most important factor. A specification for it would be next to impossible to make at the present time owing to the variable conditions that exist in engine construction.

Before the hardness and analysis of valve-heads could be standardized, the hardness and analysis of cylinders would have to be established. It is believed that the cast-iron valve-head should be slightly softer than the cylinder iron on which the valve seats. The problem for each engine builder using this type of valve is to obtain a valve to suit his particular conditions with respect to cylinder hardness and chemical composition, which vary considerably today.

The reasons for recommending that the valve-head be slightly softer than the cylinder are many, but possibly the most important is that relating to service, as it is easier and less expensive to replace a valve than a cylinder. If the valve-head is harder than the cylinder, the seat in the cylinder will in time become "pounded out."

A chemical composition which, together with certain casting conditions, will produce a very soft and weak iron is to be avoided. Obviously a certain amount of strength is necessary, this meaning a proper percentage of combined carbon. Valve-heads should be made from an iron having a slightly less percentage of combined carbon than the cylinder with which it is to be used.

There are three general classes of cast-iron-head valve: (*a*) with heads electrically welded on, (*b*) with heads welded on by means of the acetylene torch and (*c*) with heads cast directly on the stem. Whichever process is used, annealing of the heads is necessary after welding, this operation affecting the resultant chemical composition with respect to the amount of combined carbon.

LOCK WASHERS

The S. A. E. Standard for Lock Washers, published on page C5 of the S. A. E. HANDBOOK, was adopted by the Society in 1911. It includes a light series and a heavy series for S. A. E. Standard bolts and machine screws. The standard has been criticised as not being comprehensive enough for general automotive work, especially for motorcycle practice against soft metal. This has been discussed at length by members of the Motorcycle Division in joint session with members of the Parts and Fittings Division and the Lock Washer Manufacturers Association. It has been decided that the standard should be revised, but limited to three sections of steel for a given bolt size. E. W. Hart was designated to formulate a recommendation for submission to the automotive industry. This is reproduced in the drawing and tables on the opposite page. It is requested that the members of the Society review the recommendation carefully as the subject is of direct interest to all connected with the design and construction of automotive vehicles or parts. Comments and criticisms should be sent to the office of the Society.

HEAD-LAMP ILLUMINATION

A joint meeting of the Illuminating Engineering Society's Committee on Automobile Vehicle Lighting and the Lighting Division of the Society's Standards Committee was held on June 29 in New York City to discuss the advisability of revising or extending the present recommendation for Head-Lamp Illumination so that vehicles equipped with gas headlamps can comply with it. The discussion indicated that final action will have to be based on laboratory and road tests and arrangements have been made for the running of such tests as are considered necessary.

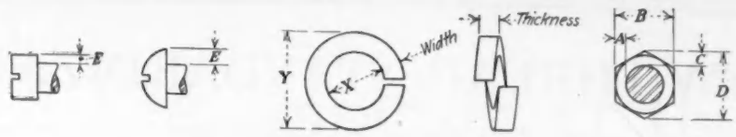
PAYROLLS IN EUROPE AND AMERICA

AN American company operating in Great Britain and France as well as the United States has prepared a comparison of rates of pay in those countries based on payroll rates prevalent in November, 1920. This shows a rate of 61.8 cents per hr. for the United States, 37.0 cents for France and 32.5 cents for Great Britain. It is stated that in considering these rates it must be borne in mind that the production per man per hour in France and Great Britain is not equal to that in America, and that the cost of production of similar articles in Great Britain and France is very little, if any, below the cost of production here.—*National Implement and Vehicle Association Journal.*

BLUEPRINTS

THE blueprints will never be discarded, and the point at which to choose between full-sized blueprints and reduced scale photoprints should be easily decided. Perhaps it would be well to make a tracing and work from blueprints for a time until it becomes apparent that no more changes will be made immediately and then photograph.

The only difference between a drawing for a full-sized tracing and one for the reduced photoprint aside from inking and cleaning is that the figures and notes should be made larger in proportion, but this does not detract in the least from the value of the average blueprint.—Harry Senior in *American Machinist.*



PROPOSED DIMENSIONS OF LOCK WASHERS.

Fillister Head Machine Screws

Screw Number	Diameter		Clearance[1]	E	X	Standard		Special Light		Special Heavy	
	Screw	Head				Section[2]	Y	Section[2]	Y	Section[2]	Y
2	0.086	0.132	0.003	0.023	0.089	1/32×0.022	0.1515	0.022×0.022	0.1330	1/32×1/32	0.1515
4	0.112	0.175	0.003	0.031	0.115	1/32×1/32	0.1775	1/32×0.022	0.1775	3/64×1/32	0.2087
6	0.138	0.217	0.005	0.040	0.143	3/64×1/32	0.2367	1/32×1/32	0.2055	3/64×3/64	0.2367
8	0.164	0.260	0.005	0.048	0.169	3/64×3/64	0.2627	3/64×1/32	0.2627	1/16×3/64	0.2940
10	0.190	0.303	0.010	0.056	0.200	1/16×3/64	0.3250	3/64×3/64	0.2937	1/16×1/16	0.3250
12	0.216	0.345	0.010	0.065	0.226	1/16×1/16	0.3510	1/16×3/64	0.3510	5/64×1/16	0.3822
						Round Head Machine Screws					
2	0.086	0.154	0.003	0.034	0.089	1/32×1/32	0.1515	1/32×0.022	0.1515	3/64×1/32	0.1827
4	0.112	0.202	0.003	0.045	0.115	1/16×1/32	0.2400	3/64×1/32	0.2087	5/64×1/32	0.2712
6	0.138	0.250	0.005	0.056	0.143	5/64×1/32	0.2992	1/16×1/32	0.2680	5/64×3/64	0.2992
8	0.164	0.298	0.005	0.067	0.169	5/64×3/64	0.3252	5/64×1/32	0.3252	3/32×3/64	0.3565
10	0.190	0.346	0.010	0.078	0.200	3/32×3/64	0.3875	5/64×3/64	0.3562	3/32×1/16	0.3875
12	0.216	0.394	0.010	0.089	0.226	3/32×1/16	0.4135	3/32×3/64	0.4135	1/8×3/64	0.4760

S. A. E. Standard Bolts

Bolt Diameter	Clearance[1]	A	B	C	D	X	Standard		Special Light		Special Heavy	
							Section[2]	Y	Section[2]	Y	Section[2]	Y
3/16 No. 10	1/64	...	...	.....	.....	13/64	5/64×3/64	23/64	1/16×3/64	21/64	5/64×1/16	23/64
1/4	1/32	3/32	3/8	0.128	0.505	9/32	3/32×1/16	15/32	3/32×3/64	15/32	3/32×5/64	15/32
5/16	1/32	3/32	1/2	0.133	0.578	11/32	1/8×1/16	19/32	1/8×3/64	19/32	1/8×3/32	19/32
3/8	1/32	3/32	9/16	0.137	0.650	13/32	1/8×3/32	21/32	1/8×1/16	21/32	1/8×1/8	21/32
7/16	1/32	3/32	5/8	0.173	0.722	15/32	5/32×1/8	25/32	5/32×1/16	25/32	5/32×5/32	25/32
1/2	1/32	1/8	3/4	0.183	0.866	17/32	11/64×1/8	7/8	11/64×1/16	7/8	11/64×11/64	7/8
9/16	1/32	5/32	7/8	0.224	1.011	19/32	3/16×3/32	31/32	3/16×3/32	31/32	3/16×3/16	31/32
5/8	1/32	5/32	15/16	0.229	1.083	21/32	13/64×5/32	1 1/16	13/64×3/32	1 1/16	13/64×13/64	1 1/16
11/16	1/32	5/32	1	0.234	1.156	23/32	7/32×3/16	1 5/32	7/32×1/8	1 5/32	7/32×7/32	1 5/32
3/4	1/16	5/32	1 1/16	0.239	1.228	13/16	1/4×3/16	1 5/16	1/4×1/8	1 5/16	1/4×1/4	1 5/16
7/8	1/16	3/16	1 1/4	0.284	1.444	15/16	17/64×3/16	1 15/32	17/64×5/32	1 15/32	17/64×17/64	1 15/32
1	1/16	7/32	1 7/16	0.330	1.660	1 1/16	5/16×1/4	1 11/16	5/16×3/16	1 11/16	5/16×5/16	1 11/16
1 1/8	1/16	1 1/4	1 5/8	0.376	1.877	1 3/16	3/8×1/4	1 13/16	3/8×3/16	1 13/16	3/8×3/8	1 13/16
1 1/4	1/16	9/32	1 13/16	0.422	2.093	1 5/16	7/16×1/4	2 3/16	7/16×3/16	2 3/16	7/16×5/16	2 3/16
1 3/8	1/16	5/16	2	0.468	2.310	1 7/16	7/16×5/16	2 5/16	7/16×1/4	2 5/16	7/16×3/8	2 5/16
1 1/2	1/16	11/32	2 3/16	0.513	2.527	1 9/16	1/2×5/16	2 9/16	1/2×1/4	2 9/16	1/2×3/8	2 9/16

All dimensions in inches.

[1]Inside diameter of washer less diameter of bolt or screw.

[2]The width of the washer is always given first; as 1/4 x 1/8, 1/4 being the width and 1/8 the thickness.

SCREW-THREAD STANDARDIZATION

CONCURRENTLY with the recent issuance of the progress report of the National Screw Thread Commission, the American Engineering Standards Committee sectional committee on Standardization and Unification of Screw Threads, for which the Society and the American Society of Mechanical Engineers are sponsors, began to function. The Sectional Committee was organized primarily to consider the Report of the Commission and the adaptability of the recommendations thereof to practice, and to provide a suitable body for eventually negotiating international screw-thread standards, especially with Great Britain. Similar work in England is conducted by the British Engineering Standards Association, which is much the same as the American Engineering Standards Committee in scope and purpose. C. le Maistre, secretary of the British Engineering Standards Association, at the time of his visit to America in 1919, showed considerable interest in the progress being made in this country toward more complete screw-thread standards, their correlation with foreign standards, particularly the British, and their general adoption in America. This was about the time that the American Engineering Standards Committee began to take definite form and Mr. Le Maistre stated that as the British Engineering Standards Association was anxious to confer with American representatives on this work, an organization such as the American Engineering Stadards Committee was recognized as the logical one within which all American interests could be represented and through which international consideration of this subject could be best negotiated. It was therefore largely by reason of the request of the British Engineering Standards Association that the Sectional Committee was organized.

The report of the National Screw Thread Commission was at that time in process of development, public hearings being held at various industrial centers. In September, 1919, a special committee of the Society[1] was appointed by President Manly to review the tentative report of the National Screw Thread Commission and suggest any changes that seemed desirable for automotive practice.

The first meeting of the Sectional Committee was held in New York City, June 9, 1921. Luther D. Burlingame and Ralph E. Flanders were elected chairman and vice-chairman respectively with C. B. LePage as secretary. It was recommended that George E. Hammann and E. H. Reed be elected members of the committee to represent the machine-screw manufacturers. It is the intention to secure an additional member qualified to represent the structural-steel interests. The members of the Sectional Committee are:

Representing the American Society of Mechanical Engineers

A. R. Baylis
Elwood Burdsall
L. D. Burlingame, *Chairman*
G. S. Case
S. G. Flagg
R. E. Flanders, *Vice-Chairman*
E. M. Herr
A. M. Houser
A. H. Moore
W. R. Porter
F. O. Wells

Representing the Bureau of Standards

H. W. Bearce

Representing the Society of Automotive Engineers

P. W. Abbott
D. G. Baker
Earle Buckingham
E. H. Ehrman
H. E. Fromme
W. F. Graham
H. L. Horning
C. M. Manly
E. O. Spillman
O. B. Zimmerman

A brief review was given the committee of the action taken at a general meeting of machine-screw manufacturers in New York City, May 18, which favored the adoption in machine-screw practice of the National Screw Thread Commission's recommendations for the coarse-series medium-fit and the fine-series medium fit screw-threads.

A communication from the Canadian Engineering Standards Association was read to the effect that if the proposed cooperation with the British Engineering Standards Association should lead to an international conference on screw-thread standardization, it would like to participate. The Sectional Committee indicated that if such a conference were called, the Canadian Engineering Standards Association would be invited to send one or more official representatives.

Proposals were offered for consideration by the Sectional Committee embodying the following named subjects in connection with study of the National Screw Thread Commission's report:

(1) Magnitude of tolerances
(2) Distribution of neutral zone
(3) Gaging system
(4) Desirability of a large number of variations and classification of screw-thread fits
(5) Errors in lead
(6) Series of thread pitches

The general opinion of the committee was that exact information from manufacturers who have adopted the National Screw Thread Commission tolerances should be available for review by the committee. There was divided opinion as to whether the distribution of the neutral zone should be considered by the committee, but the neutral zone was thought to be impracticable in connection with some grades of screw thread, especially when it extends below basic on the screw. It was felt that the inclusion of a description of a gaging system in the National Screw Thread Commission's Report is advantageous as indicating an acceptable practical method. The system set forth in the report is offered by way of suggestion and not a definite recommendation. There was some discussion as to the desirability of reducing the classes of thread fit from eight to six by eliminating the "loose fit" on the fine threads and the "close fit" on the coarse threads.

The subject of errors in lead was not discussed at great length but the opinion was expressed by some that maintaining accuracy in lead is more important than maintaining accuracy in pitch diameter. A suggestion was made that an intermediate third series of thread pitches be adopted and that each series be made in one class of fit only.

After discussion of ways and means of studying the Commission's report, and presenting it to those interested in connection with the Sectional Committee's activity, it was thought that a condensed version of the report should be issued. A subcommittee has been appointed by Chairman Burlingame to consider this matter, as well as the five subjects brought up at the meeting as enumerated above. Those designated for this purpose are Charles M. Manly, chairman, P. W. Abbott, Earl Buckingham, G. S. Case, R. E. Flanders, G. E. Hammann and W. R. Porter.

An abstract of the progress report of the National Screw Thread Commission was published in the October, 1920, issue of THE JOURNAL. The complete report, consisting of 108 pages, is now available in printed form, having been issued by the Bureau of Standards, Washington.

[1] See THE JOURNAL, October, 1919, p. 280.

TRACTORS IN FRANCE

THE French Ministry of Agriculture has compiled statistics which show the growth in the use of farm tractors and other agricultural machines in France. In 1913 there were only 295 farm tractors in use and practically all of them were American machines. In 1920 the number had increased to 5400, most of them being of French manufacture. Three large companies have developed their production of agricultural machinery so that they are setting aside a percentage for export.—*National Implement and Vehicle Association Journal.*

Vol. IX August, 1921 No. 2

The Mutual Adaptation of the Motor Truck and the Highway

By A. T. GOLDBECK[1]

SEMI-ANNUAL MEETING PAPER

FRANKLY, the aim of this paper is to stimulate thought on an idea that is not new, but to which little attention has thus far been given. My excuse for asking you to consider and think hard about it is my earnest desire, and it must also be your desire, to see accomplished the greatest possible economy in transportation over our highways. Here is the fundamental proposition. Expense of highway transportation involves a large number of items, which may be grouped into those directly concerned with motor-truck operation and those involving the highway, and our aim should be to devise our highways and our motor vehicles and adapt them one to the other so that the greatest economy of transportation will result.

The ultimate cost of highway transportation is borne by the public, who are very much interested in seeing this cost reduced to a minimum. It is of very little concern to the ultimate consumer how it has been possible to reduce his transportation bill. He cares little whether this economy has been effected for him by vastly increasing the economy of actual operation of the motor vehicle, or the saving has been brought about through reduced cost of construction and maintenance of his roads. He sees the final result, low cost of freight transportation by motor vehicle, and is satisfied that here is a sound reliable and lasting utility which it will pay him to encourage, patronize and support.

DESTRUCTION OF ROAD SURFACES

There is no need of dwelling on the enormous destruction of our road surfaces in the past several years. We all know that something is radically wrong when a road disappears in a single season and sometimes overnight. We do not have to ponder to arrive at the conclusion that when such conditions obtain there must surely be tremendous waste in that kind of highway transportation. The blame need not be laid on any one in particular, for stress of circumstances was responsible for imposing on our roads an unpredicted and unprecedented volume and weight of traffic.

Certainly no one desires to see our highways, constructed today, destroyed in the next 2 or 3 years, for their reconstruction is a long and tedious operation and increases very materially the cost of our highway transportation bill. I take it that we all wish our roads to have a life compatible with ultimate economy in their use. We would like to see types of roads constructed that will carry their traffic with the least possible combined road and vehicle cost. Surely that is an ideal to be sought after, and it goes without saying that both highway and automotive engineers must be supplied with very definite facts before they can design their particular parts of such an ideal motor transportation system, in which the motor vehicle and the highway are so mutually adapted to each other that the most efficient transportation will result. Right now these facts do not exist. In their place we have legislation that limits the maximum loads to be carried on the highways and the speed with which the motor vehicles are to run, and imposes license fees that are not based on scientific fact. Legislation has been necessary to prevent the too rapid destruction of the highways and of necessity has been arbitrary legislation which possibly may not result in giving the public the greatest return for the money expended. Thus, the maximum weight of truck is limited to a certain figure because weights above this amount have caused rapid destruction of the roads. Yet certain types of hauling can undoubtedly be done with heavy units of traffic, and were the figures and facts available it might be found that where this kind of hauling is necessary much economy would result in rebuilding the highway so that it will carry the heavy units of traffic. Again, it may be that although the particular kind of hauling can be done most cheaply with heavy units of traffic, so far as actual motor-truck operation is concerned, it may nevertheless pay to increase the motor-truck operation cost somewhat by using lighter units and thus effect a saving in the items of road expense.

Unfortunately, facts are not available, and the automotive engineer and the road engineer should get together and gather information that will give them a more definite basis upon which to decide on the design of the truck and the design of the road. At present each is deciding for himself on his own particular problem with too little consideration of the aim to be accomplished, ultimate economy in highway transportation.

DESIGNING THE TRUCK TO CONSERVE THE ROAD

I wonder how much thought has been given on the part of the automotive engineer to the problem of motor-truck design with the idea of road conservation. It would seem that much might be accomplished by the motor-truck designer toward attaining an ideal transportation system if he would give considerable thought as to what effect his latest creation will have on the road. I am wondering whether the automotive engineer could not with advantage follow in the footsteps of his brother designer of the locomotive. When it was found economical to increase the weight of trains and the weight of the locomotive from the standpoint of operation of the train, it was likewise found economical to distribute the weight of the locomotive on more wheels so that the destruction of the roadbed and the track might be kept within reasonable limits.

Unquestionably, the bulk of our serious road destruction results from heavy wheel concentrations, granting, of course, defective design of drainage, subgrade and road surface as attendant contributory causes. This being the case, would it not seem desirable for the motor-truck designer to look into the question of distributing the weight on his heavy trucks to more than four wheels or even more than six? Except so far as bridges are

[1]Engineer of tests, Bureau of Public Roads, Washington.

concerned, I can see no reason for limitations on the gross load of the motor truck provided it is distributed over the road surface so that the wheel concentrations are kept within reasonable bounds. I realize that there must be tremendous mechanical difficulties to be overcome in such a design but if it pays, always keeping in mind the ultimate cost of haul, surely they can be overcome. In working out the possibilities of designs, is it not evident that the highway engineer and the automotive engineer must get together and pool their ideas? How big the wheel concentrations should be and what the minimum desirable spacing is, are problems for the highway engineer; the mechanical troubles will be solved by the motor-truck designer.

As a result of several years of research made with the idea in view of more rational design of highways, the Bureau of Public Roads has developed facts which lead us to believe that real conservation of our roads could surely be attained if it were practicable and economical from the motor-vehicle standpoint to apply these facts to the design of the motor truck. In a previous paper before the Society[2] attention has already been called to the manner in which heavy wheel concentrations are distributed through the road surface to the underlying subgrade. It has also been pointed out that by actual field and laboratory tests of the Bureau of Public Roads we have shown that these wheel pressures created pressure intensities on the subgrade that may greatly exceed the bearing value of the subgrade at various times in the year. Of course, when such a condition obtains it is not long before the road surface is so badly distorted that it breaks up under traffic, and the remedy is more expensive road construction because of the necessity for increased thickness of surface, better drainage or expensive subgrade treatment. Had the wheel concentrations been smaller, in very many cases the pressure carried to the subgrade would not have exceeded the subgrade support. The surface would not have been badly distorted and the road would have served the traffic for years. It must be perfectly plain in cases of this kind that by reducing wheel concentrations we effect real economy through the conservation of the road. Reduction of wheel concentration does not mean reduction in the total load carried by the truck; it may mean an increased load. But it does mean either a more equal distribution of the load on the wheels or it may mean the use of more wheels.

As some of you have no doubt been following our impact studies, you have noted the vast difference in the impact pressure produced on the road surface by a moving truck, depending upon its tire equipment.[3] You have observed how greatly the impact effect on the road is reduced, depending upon the cushioning properties of the tire. You have seen how tremendous the impact can be when the solid tire wears down to an inch in thickness. You have also noted the better cushioning qualities of tires having high static deformation and, finally, you no doubt noticed the extremely small impact produced when the truck was equipped with pneumatic tires. These facts are very significant. From the road engineer's standpoint they indicate the possibilities, at least, of road conservation through the use of proper tire equipment, and tremendous possibilities in road conservation were it entirely practicable to use tires having the highest cushioning properties. No doubt there are other items of truck design affecting its destructiveness to the road surface, but it is not my wish to go into a detailed discussion of this phase of the problem at this time. I simply mention these few points to bring to the attention of the automotive engineers the possibilities of their great assistance in bringing about decreased cost in highway transportation through the design of the motor vehicle in such a way that it will conserve the road surface without necessarily decreasing the actual motor-truck economy. The possibilities are apparent. Why not definitely establish the facts and apply them to advantage?

Society Cooperation with Highway Officials

We must arrive at these facts through cooperative effort and what I would like to see accomplished is the formation of a joint committee by the Society and a highway engineering organization such, for instance, as the Association of State Highway Officials. I would like to see this committee study the highway transportation problem with the ultimate idea of decreasing the cost to the public of highway transportation. This will involve studies that will show what types of road construction and what types of vehicle are best suited to one another, for particular stretches of road carrying definite commodities. Such a cooperative committee could make a thorough study of the effect of the motor truck on the road and, working in close harmony, could determine whether it is practicable or desirable to suggest changes in the design of either the motor truck or the road to make them more adaptable to one another.

The highway transportation problem must be considered in its entirety in just the same way that the problem of railroad transportation is considered. The time has certainly arrived when the motor-vehicle department and the road department of our highway transportation system should work in close harmony. They should understand each other's difficulties and work with that spirit of cooperation which will lead to the most efficient results. A committee such as I advocate will do much to bring about this cooperation and there is no doubt that through its studies facts will be established which will reduce greatly our highway transportation costs.

[2] See THE JOURNAL, April, 1921, p. 339.
[3] See *Public Roads*, March, 1921.

Commercial Aviation in the Eastern Hemisphere

By Edward P. Warner[1]

Annual Meeting Paper *Illustrated with* Photographs and Drawings

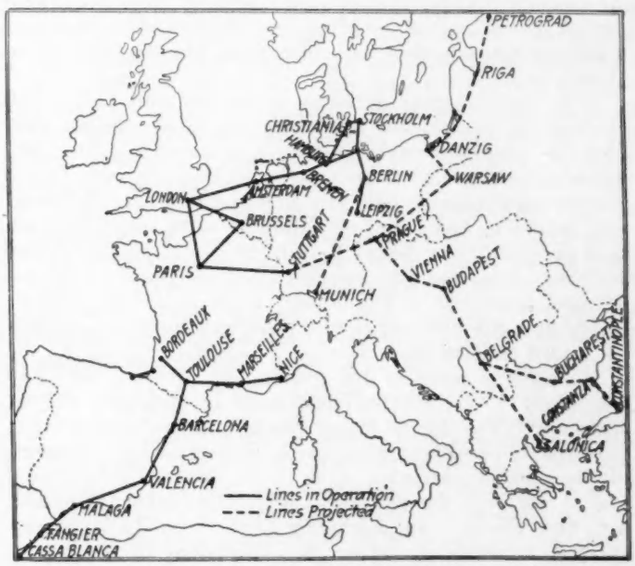
COMMERCIAL aviation in Europe as in America may be said to have sprung full-fledged into being shortly after the signing of the Armistice. Although attempts had been made at commercial flying before 1914, a few wealthy men having used airplanes for hasty trips from one city to another and some abortive attempts having been made at mail carrying as a "stunt," the flying done had no real significance except as propaganda for the airplane in general and had little more significance in that respect than had the exhibitions which were a common feature of State and County fairs and other fêtes in this country. One exception must be made to this statement. The Hamburg-American line had been running, with the Schwaben and other Zeppelin airships, lines between some of the large cities in Germany, as well as making excursion tours over Berlin, and had been meeting with some success, although the public support probably was not large enough to make the operation of this line a paying venture aside from its value in developing the airships and in giving data on their operation which were subsequently put to military use.

The enormous development of aircraft under the stress of war not only increased the reliability of airplanes and airships and made it more practicable and safer to employ them in commercial flying, but it also awakened the public to the fact that flying is a reality, that it is a mode of locomotion possible for everyone and not merely for a few supermen, trick bicycle riders and acrobats; and it furthermore involved the creation of a large supply of aircraft which inevitably stood idle after the signing of the Armistice and invited every effort to find for them some new non-military use. Commercial flying, despite these incentives for its commencement, was a little slow in starting after the coming of peace, as all European governments hesitated to throw open the air in their territory to indiscriminate navigation before they had had a chance to make a thorough study of the conditions to be imposed on such navigation and of the control which would have to be exercised in the interests of the safety of the State and the safety of its nationals.

Civil flying in England was officially opened under authorization of the Air Ministry, May 1, 1919. Although a little passenger-carrying had been done over the Easter week-end, 10 days before that date, it had been strictly limited to service types of machine and to ex-service pilots and to flights extending not more than three miles from the home field. On May 1, however, the Air Ministry issued its regulations for the operation of civil aircraft, and those regulations are substantially the ones under which flying is carried on to-day, as they were nearly identical in most respects with the terms of the International Air Convention adopted by the Peace Conference of Versailles.

[1] Jun. M.S.A.E.—Secretary, sub-committee on aerodynamics, National Advisory Committee for Aeronautics, Langley Field, Va.

For the first few months after the official opening of civil flying in the British Isles, the work was confined to passenger-carrying by special request and to attempts on a small scale at the carrying of mails within the British Isles. This mail carrying, like all that which has since been done in the major European countries, was done by operating companies receiving a fixed fee from the Government. No European power operates its own mail planes, as has been the practice here.



Projected and Regularly Operating Air Routes in Europe at the Beginning of 1921

International flying between England and the Continent began Aug. 26, 1919, the International Air Convention having then been drawn up and ratified by the principal states. A line between London and Paris was started at once to carry passengers, express and mail, but the mail carrying was of negligible importance for a considerable time, as the rates charged for postage were almost absurdly high; the letter postage being 2 shillings at first. The postage and the express services were well patronized from the beginning and the first line was soon joined by several others, so that there are now five distinct services in operation between the London and Paris terminal airdromes. In addition to these services there are now functioning regular lines between London and Brussels, London and Amsterdam, Paris and Brussels, Bordeaux and Nice, Amsterdam, Hamburg, Copenhagen, and Berlin, Toulouse and Casablanca via Tangier, and on a few other less important routes. This does not include a number of services which are advertised as regular but do not, as a matter of fact, run except on particular occasions when passengers offer themselves. In Germany, for example, there are fixed fares

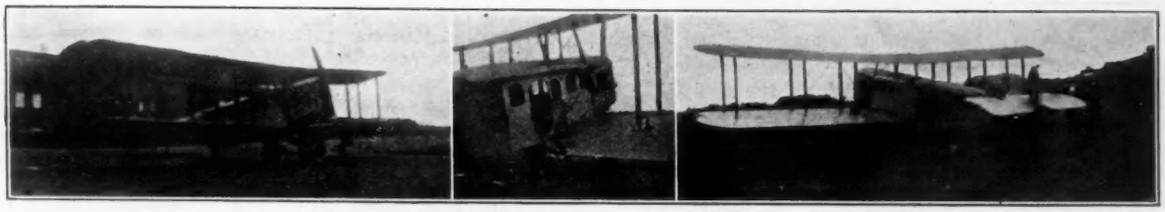
over about 100 routes within the German Republic, but no regular journeys on fixed schedules except in one or two instances or except on such special occasions as the Leipzig Commercial Fair when numbers of passengers were carried from Berlin by airplane. Much more ambitious projects also are under consideration, one in particular being planned to connect Paris with Central and Eastern Europe, the fundamental line being from Paris to Prague with extensions leading to Warsaw, Nish, Salonica, Budapest, Constantinople, Bucharest and Constanza. The lines in operation and projected are shown in Fig. 1. Some routes of course offer much more favorable opportunities than others for aerial transport. The chief requirements for a good airplane route are that the traffic shall be large and wealthy, that the terrain shall not be excessively wild or mountainous, and that surface travel shall be slow and uncomfortable. All of these requirements are satisfied in the highest degree by the London-Paris and London-Brussels routes, the Channel crossing in a small steamer in bad weather, with two trans-shipments of hand baggage, being an atrocity of the first order. Again Great Britain finds the Channel of assistance in building up the potential means of national defense, this time in a most unexpected and indirect way.

The international services were not well patronized during the winter, but the traffic increased steadily during the past summer. During the month of July, 933 passengers traveled from London to Paris by air, 10,554 letters were carried between England and the Continent and goods to the value of £100,750 were imported into and exported from Great Britain by air in August. The number of commercial aircraft crossing the Channel increased from 140 in September, 1919, to 486 in August, 1920, and the average size of the airplanes in use also increased constantly.

No airship services are running at present, but they are likely to be started soon both in England and in Germany. The Air Ministry has offered to furnish rigid airships to operating companies, and some long-distance service would probably have been started before now had it not been for the great economic tension throughout the world. In Germany, the Zeppelin company started immediately after the Armistice to operate a service between Berlin and Friedrichshafen with the Bodensee, a ship of only 700,000 cu. ft. but far more efficient than anything previously built. The Bodensee has since been enlarged, and the Zeppelin officials declare themselves anxious to re-start the service with the Bodensee and her sister ship the Nordstern as soon as they can secure guarantees from the Allies that these ships will not be confiscated under the terms of the treaty of Versailles as soon as they are put in commission. The airship is the ideal vehicle for long routes with moderately heavy traffic, and there should be an excellent opening for trans-Atlantic lines and for lines from England to India and to South Africa. The civil service in India would be considerably more attractive if Calcutta were only three and one-half days from London and two weeks could be spent at home out of a three weeks' annual leave. The airship has little chance in commercial work, however, as long as the present difficulties with landing and housing persist, and it will be a success when, and only when, the mooring mast is perfected to a point where a large rigid airship can be moored out continuously and in all weathers.

The first necessity of passenger carrying by air is public confidence in the reliability and safety of the service. People are willing to send their letters where they will not trust themselves, and commercial passenger-carrying by air can never really succeed unless it has public opinion and a supporting press behind it. The British undertakings have been very fortunate in this respect from the first, and the commonplace manner in which travel by air is now accepted by the general public is amazing to a foreign visitor. On entering a tourist agency in London at the present time and asking for a ticket to Paris, one is regularly met by the matter-of-fact query, "rail or air?", and the same question is put when express packages are brought in for shipment to the Continent. There is one agency in London which handles air traffic almost exclusively, its other business being purely side-lines, the adjective "aerial" appearing in the very name of the corporation, and this agency has established itself on the ground floor on a corner in Piccadilly Circus, one of the busiest spots in London. The condition is somewhat comparable to that which would exist if an American airplane ticket-agency took space 30 x 45 ft. on the ground floor at the corner of Fifth Avenue and 42nd Street in New York City. In Germany the booking of air passages forms an important part of the business of the Hamburg-American agency in the Unter den Linden. That public confidence exists in so large a degree is largely due to the favorable attitude of the press which, instead of seizing every opportunity to present accounts of accidents under glaring headlines and to magnify their significance, has been uniformly friendly and has sought rather to emphasize the news favorable to aviation both in the news columns and editorially. The friendly attitude of what is probably the largest of all newspaper syndicates is traditional, Lord Northcliffe's personal interest in aviation having extended far back into the pioneer days and been expressed in concrete form by the offer of large prizes for the trans-Atlantic flight and other aerial feats.

No matter how friendly the newspapers may be, however, they can do no more in the long run than to make a fair presentation of the facts and it is impossible for commercial aviation to flourish unless the safety of flight is fairly comparable with that of other means of transport. In order that reliable data on this point may be at hand, the British Air Ministry has compiled statistics relating to accidents in commercial flying, both to furnish for designers information on the causes of such accidents and the best means of preventing their recurrence and to permit the public to judge fairly of the risk which they run in traveling by air. These statistics show that during the first eleven months of commercial flying in England and between England and the Continent there was a total of 24 accidents, four of which resulted in the death of one or more occupants of the airplane. The pilot was killed in all four cases, while in the whole 11 months one pasenger was killed. The average death rate among pilots was 0.415 per 1000 hr. or one death for every 2410 hr. of flying, while the average among passengers was 0.015 fatalities per 1000 passengers carried and 0.055 per 1000 passenger hr. This works out roughly at one death for every 67,000 passengers and every 18,200 passenger hr. or, taking the average cruising speed of commercial aircraft as 90 m.p.h., as one fatality for 1,640,000 passenger-miles. During the year 1917 the passenger death-rate for railroad travel in the United States was one for every 3,220,000 passengers carried, a danger ratio of 48 to 1. In some years American railroads have shown themselves less than 20 times as safe as has the airplane in this, its first,



FRONT AND REAR VIEWS OF THE WESTLAND LIMOUSINE AIRPLANE, WITH THE ENTRANCE TO THE CABIN IN THE SMALL CENTRAL ILLUSTRATION

year of commercial use. If the calculation includes all injuries as well as deaths, the relative showing of the airplane is considerably more favorable. The airplane death-rate is certainly very much less than the uninitiated would generally suspect, but it is still much too high and must and can be further reduced by research, by improvement in design, and by more complete and systematic ground organization, all of these call for Government aid.

Second only to safety in importance, and even ahead of it insofar as the carriage of mails and express is concerned, is economy. The cost of air services is still rather uncertain, as the lines have not been in operation long enough to give very many data on depreciation and running costs. The most exhaustive study to date is that made by H. White-Smith in a paper presented to the Air Conference held in London last September. Mr. White-Smith analyzed the costs of operating a service with several types of airplane and seaplane, including some new machines of commercial types and some converted service airplanes, and showed that the most economical machines, the largest ones in most cases, could operate profitably carrying passengers between Paris and London for £5, 10s. ($19.50 at the present exchange), if the machines could carry a full load on every trip. Mr. White-Smith's figures were based on a life of 3000 flying hr. for the airplane and 2000 flying hr. for an engine and included insurance against crashes at a rate of 15 per cent. The Canadian Air Board recently issued a memorandum on depreciation in which the conclusion was drawn that the life of an airplane under ordinary use is 700 flying hr. and that the crash risk is 0.2 per cent every flying hour, so it is evident that there is still wide difference of opinion among the authorities on the basis to be adopted in calculating costs. In durability, as in safety, there is room for decided improvement, and there is no doubt that flying life will be much increased in the near future.

The actual costs have shown a tendency to steady reduction. The fare charge on the London-Paris route was originally 20 guineas but has since been decreased several times and now stands at 10 guineas ($37.00) for the one-way journey and 18 guineas for the round-trip. The fare to Brussels is the same, while that to Amsterdam is 15 guineas one way. The rate between London and Paris by boat and rail via Dover and Calais is £3, 15s., 8d., so that the excess of airplane fare over that for service transportation is 178 per cent. Frank Searle, manager of the Aircraft Transport & Travel Co., who was largely responsible for the reduction in rate, lays great emphasis on the necessity of reducing the fare still further to increase the use of aerial transport to a point where machines can be run in considerable numbers, thus decreasing the percentage of overhead to be charged to each trip and also in order that they can run regularly with a full load. Mr. Searle prophesied, in an interview in the London *Times*, the reduction of the London-Paris fare to seven pounds in the relatively near future. The fares on other services are of the same order except in Germany, where the extreme depreciation of the currency makes all costs ridiculously low when referred to American money. The fare between Berlin and Leipzig during the Leipzig fair, for example, was only 800 marks, the equivalent of about $15 as the exchange then stood.

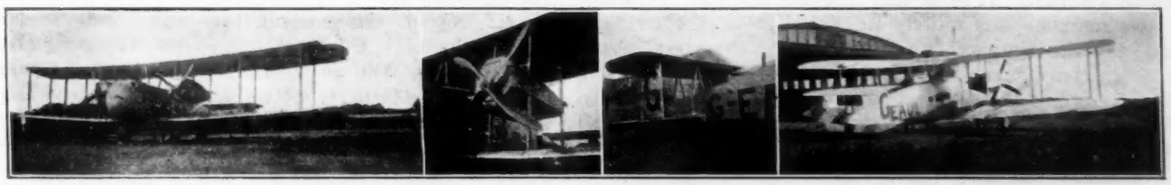
The charge in England for an "aerial taxi" for two people is 2s. 6d. (44 cents) per mile, and an airplane can usually be had to start for anywhere on an hour's notice. This fare is only 2½ times as large as that for an earth-bound taxi in London, and it costs approximately the same amount to travel by airplane in England and by taxi in New York.

INSURANCE

An essential to any business is insurance, and that is now being handled by a number of firms. Particularly interesting is the invasion of the field by Lloyds' who have recently retained consulting aeronautical engineers with a view to registering aircraft and rating them as risks, just as they have done with ships for many years. It appears that the aerial, like the marine, underwriters will be far harder on the man responsible for an accident than will the State, and it has already been suggested that a crash in landing is absolutely inexcusable and that a pilot who once damages an airplane in landing on a good field should be made forever uninsurable.

Insurance rates at the present time are about 30 per cent per annum for passenger aircraft traveling over good country, with a reduction of 0.2 per cent on the face value of the policy for every hour of flying after the first 100 hr. Airplanes used for stunting cannot be insured ordinarily.

There are practically no data on which to base an estimate of the cost of an airship service, but Air Commo-



FOUR VIEWS OF THE VICKERS VIMY COMMERCIAL AIRPLANE EQUIPPED WITH A ROLLS-ROYCE EAGLE ENGINE

dore E. M. Maitland has estimated that with ships similar to the R-34 a 15 per cent profit could be made carrying passengers from England to Egypt for £50, to India for £100, and to Australia for £190. These figures are from 10 to 70 per cent in excess of the first-class steamer fares, and the saving of time would be from 60 to 70 per cent.

Government Assistance

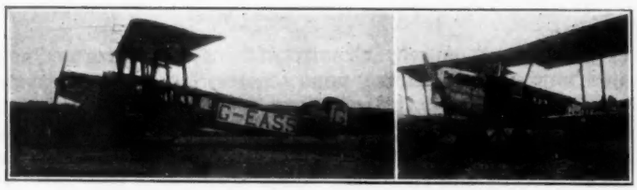
There is no European nation which has not clearly seen that the airplane can be kept in readiness for use in war only through the development of its use in commerce and that it is a clear function of Government to assist their use in commerce by every means in its power. The development of an air traffic under the control of its nationals is felt to be more important to many States than is the development of a similarly controlled merchant marine. In addition to the direct military usefulness of the airplanes developed for commercial work there is an additional motive in the value of air transport as a link between the home country or the dominions or colonies, and an analysis of the measures taken by the various Governments shows that this last incentive is always in mind and it has been the guiding star of such enterprise as the Government-encouraged, although not actually Government-assisted, flights from England to South Africa and from England to Australia in the development of the "Imperial Air Routes" of which more will be said later, and in the efforts of the French and Belgian Governments to steer air commerce in the direction of their respective colonies in West Africa. Every improvement makes it easier for the dominions and binds them more closely to the parent country.

If the necessity of Government assistance of some sort in giving commercial flying its start is conceded, there are four forms which it may take. It may be extended through direct purchases of airplanes for the military establishment or for other branches of Government, as is the case here. Secondly, it may take the form of a direct subsidy of the industry, of the payment of part of the costs of recognized airplane forms by the Government, thus making it possible to reduce the cost of operation of transport lines. A modification of this scheme, and one more commonly adopted, is the granting of monetary assistance by the Government to operating companies, instead of to manufacturers, on a basis of services actually operated and proportionate to the extent of the service. This is the system on which the French Government has chiefly proceeded and it is also to be adopted by the Polish Government to encourage the opening of the service between Prague and Warsaw. Finally, instead of granting any direct assistance to firms engaged in the manufacture or operation of aircraft, the Government may offer indirect assistance by furnishing the ground organization for the services and by encouraging research aiming to obtain fundamental data for the production of more useful and more economical aircraft. It is to this last method that the British Government has chiefly adhered up to the present time. At the time of the opening of commercial aviation, Winston Churchill, then Secretary of State for Air, voiced the opinion that commercial aviation must fly alone, and despite occasional protests and appeals for help the British Government has adhered throughout to that policy. The assistance granted in Great Britain has included the provision and upkeep of state airdromes open to both commercial aircraft and those owned by private individuals. Hangars can be rented at these fields and supplies and repairs of all sorts can be secured. At present, there have been listed over 300 fields in the British Isles which are available for use by civilian pilots; this does not include emergency landing places, but only regular fields kept in proper condition for the reception of aircraft. If flying fields were distributed with the same intensity over here there would be 130 in New York State alone. The number now available, however, is felt to be insufficient for convenience and safety, and it has been proposed recently that the major air routes be marked by a continuous strip of cleared ground about 100 yd. wide, permitting of a forced landing at any point along the route. This strip would be lighted continuously for night flying and a charged cable would possibly be laid along the route to permit of electric direction-finding in a manner similar to that employed in recent experiments with shipping in New York harbor. No official steps looking toward such elaboration of the air routes have been taken as yet, however. The most notable achievement of the Air Ministry in long-distance route-marking was the laying out of a line of landing fields from Cairo to Cape Town, and another string partially covering the road to Australia. Great central airdromes for travel to the dominions have been established at Karachi and at Heliopolis, near Cairo. The courses followed in the path-finding flights which marked out the Imperial air routes, made by Sir Ross Smith and Captains Broome and Cockerell and Captain Ryneveld, are shown in Fig. 2, together with the trans-Atlantic courses of Sir John Alcock and of the NC-4. Furthermore, the State maintains an elaborate meteorological service preparing a special weather map for aviators daily and sending out weather bulletins by radio at frequent intervals throughout the day, and it has erected two aerial light-houses at Croydon and Lympne, the latter of which points lies virtually on the London-Paris route. Concerning the terminal customs airdrome at Croydon, I shall have something more to say later.

Night flying on regular services has not yet been undertaken because of the danger involved. If commercial flying is to exercise any large influence on travel except on a few selected routes of a very special character, it is absolutely essential that journeys be made at night, and this calls for decided modification in the types of aircraft employed. The London-Paris route, as already remarked, is a special case where night flying is not required, as the changes of vehicles required and the crossing of the international boundary make a night journey by the ordinary means of travel rather unpleasant, but that route has little bearing on our problems here, and a daytime airplane line between Boston and Washington, for example, could never hope for any very large patronage as long as the Federal Express makes it possible to make the journey without losing 1 min. of the business day. Night-flying airplanes must be multi-engined so as to be absolutely insured against sudden forced landings, they must be specially fitted for the convenience of the passengers, and they must have a reasonably low landing-speed. In general, the high speed need not exceed 90 m.p.h. Furthermore, night flying is absolutely dependent on the provision by either the Government or private enterprise of an elaborate ground organization, including numerous well lighted landing-fields and many aerial lighthouses or searchlight stations. In these respects the marine aircraft traveling between seaports and keeping over the water has a decided advantage over land types, as it can depend on marine

lighthouses already established for finding the way and as it is nearly always possible to make a safe landing on the sea with the aid of a few parachute flares and lights on the seaplane, even on a moonless night.

The British Government, in addition to providing ground organization, has continued its research activities and distributed broadcast the results of the work done at the Royal Aircraft Establishment and at the National Physical Laboratory, much of which is now planned to have a special bearing on commercial aeronautics, and it has during the past summer held a very successful competition for commercial aircraft of three types, large land machines, small land machines and amphibians. British experience points a few lessons which may be of great value to us at present. In the first place, it has always been found that commercial and military aviation must be considered separately and that the necessary research work for the commercial side can best be carried out directly by a civilian body severed as far as possible from ordinary departmental administration. This place in Great Britain is filled by the



A Side View of the Sopwith Antelope Airplane (at the Left) and One of the Nose of the Machine (at the Right)

Aeronautical Research Committee, formerly the Advisory Committee for Aeronautics, a body which is virtually duplicated in its organization and purpose and possibilities of usefulness in this country by the National Advisory Committee for Aeronautics. Secondly, foreign experience emphasizes the value of special competitions for commercial aircraft. There is no doubt that the British competitions aroused more interest among the manufacturers and did more to develop design for specifically commercial purposes than would an equal amount of money expended on purchases of designs already developed, and it is my opinion that we in America could do nothing more useful to encourage aeronautics than to plan to hold such a competition for purely commercial aircraft. The French also have had a competition, but theirs differed a little from the British one in that the French rules kept the possibility of military need always in mind and made it a condition of entry that the airplane must be of a type easily and rapidly convertible for use as a bomber.

The French Government has perhaps paid a little less attention to the establishment of ground services than has the British, but it adopted in September, 1919, an elaborate scheme of subsidization of operating companies. The subsidy is a maximum for services operating regularly between points at least 200 km. apart and is then equal to one-half of the depreciation based on an assumed life of 400 hr. for an airplane and 267 hr. for an engine. Under this system a service operating with a two-engine airplane carrying 12 passengers and costing $40,000 for the airplane without engine and $10,000 for the engines would receive an award of $75 per hr. of flight. Where the line is less than 200 km. in total length, the hourly award is halved. Additional bonuses are given for the length of voyage without stop, for the power of the engine, for the speed and for the

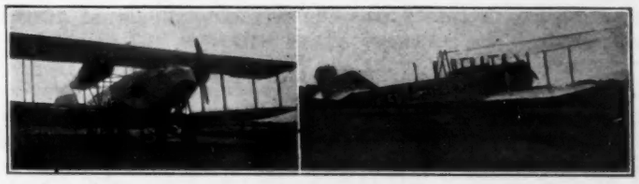
Side View (at the Left) and View of the Nose (at the Right) of a Farman Goliath Airplane Driven by Two Salmson Engines

useful load carried. Furthermore, the last two bonuses are proportionate to the nature and location of the service, being a maximum for services in the interior of Africa and a minimum for those in continental France. Here again will be noted the desire to use the airplane as a bond of empire. A still further premium is awarded for military value and for ease of conversion for bombing purposes, so that it would be easy for the airplane specified above to receive a total premium of $135 per hr. of flight or about 12 cents per passenger-mile. These premiums are available only for companies wholly French, using airplanes and equipment of French design and construction. To qualify for the premiums it is required that the total number of airplanes owned and kept ready for service as far as possible be at least three times the number actually in use at any given time and that the number of pilots be 50 per cent greater than the number flying on any particular day.

Other countries have done much less to encourage civil aviation. The German Government, owing to the restrictions of the treaty and its own impoverishment, has been unable to give any concrete assistance to German air-transport companies and little has been done by the Government in Italy or any of the smaller States. The Belgian Government is taking steps to give such support as is necessary to insure the establishment of service in the Belgian Congo and the Polish Government, as already noted, is offering a small subsidy to the company operating between Prague and Warsaw.

The Air Convention

The Governments come in contact with commercial aviation not only in extending that assistance which is necessary to keep it going, but also in exercising that measure of control which safety exacts. The control exercised is supposed to be practically uniform throughout the allied countries and those neutrals which have subscribed to the International Air Convention and the League of Nations, being regulated in detail by the terms of the Air Convention, which document provides for the licensing of aircraft and of pilot navigators and engineers, for the conditions to be observed in crossing International boundaries, and for rules of the road and lights and other signals. The Air Convention was originally intended to be a closed corporation, as it prescribed that every contracting State undertook to prevent the flight across its territory of any aircraft belonging to a non-contracting State, but a protocol was drawn up later permitting any State, which so wished,



Nose and Side Views of the Handley-Page Commercial Airplane

to nullify this particular clause, as the neutral states surrounding Germany had naturally protested against being required to bar out German aircraft until such time as Germany should be received in the League of Nations. The points of detail in the Air Convention which are of most interest to us are those dealing with international navigation. It is prescribed that any commercial aircraft of a contracting State shall have the right to cross the borders of any other contracting State without landing therein, subject to the following of such regulations as each State may lay down relative to the prohibition of flying over military or other secret areas. It is further prescribed that an aircraft making a voyage from one State into another shall land at a prescribed customs airdrome and that any forced landing at the end of an international flight shall immediately be reported to the customs authorities. Each State is given the right to restrict traffic between two points within its own borders to aircraft owned by its own nationals and elaborate provisions are laid down against the camouflaging of alien nationality behind the names of native dummy directors. This is, of course, analogous to the provisions of the coastwise shipping acts in force in America and other countries. While the air convention should very much facilitate international travel by air, in practice some difficulties have arisen owing to the present unsettled state of Europe, and commercial aircraft have been forced frequently to land in a contracting State over whose territory the pilot had planned to pass without stop. The convention has, however, very much ameliorated conditions and international intercourse would be quite impossible without some such arrangement.

The Air Convention charges each contracting State with the duty of granting certificates of airworthiness and licenses to operating personnel. The conditions for the licensing of pilots are laid down in detail, the tests not being very difficult, but it is left to each country at least for the present to make its own regulations for the granting of the airworthiness certificate. In England a memorandum has been issued treating in detail of the load factors required in commercial aircraft and of the methods of calculation of stresses, and the design of every airplane flown for hire in the British Isles has to be examined, checked and approved by the Air Ministry. No European State has any intention of permitting, if they can be prevented, such catastrophies due to improper design as have occurred too frequently in the past. Every aircraft flying on Great Britain or any other contracting State is required to carry its official designation in the form of five letters painted on the side of the fuselage and also on the bottom of the lower wing. The first of these five letters designates the nationality of the aircraft, except that in the case of a number of smaller States having the same first letter the nationality is designated by the second letter. In accordance with the terms of the Air Convention, had the United States accepted them in full, every American aircraft would have been required to bear five letters registered at Geneva, the first letter being N. The total set of five letters forms the wireless call-signal of the aircraft.

Passports and Visés

The frequency of international boundary lines in Europe, particularly since the recent redrawing of the map of Central Europe, has both favorable and unfavorable effects on commercial flying. In a flight in which several States are crossed the traveler by air is saved much inconvenience, provided the intentions of the Air Convention are realized and the aircraft is not required to land as it crosses each boundary, as only one visé would be required, whereas one who journeys by rail must have his passport viséd for every country he is to penetrate; a rail journey from Paris to Constantinople, for example, entails weary days of waiting in the ante-rooms of the consulates of the various countries of Central Europe. On the other hand, the delay in waiting for a visé or to secure a passport is a much more important relative fraction of the time of an air than of a land or water journey. The value of being able to go from London to Paris in 2½ instead of 9 hr., for example, is much decreased if two days to secure passport have to be added to the time of both trips. The passport difficulty is fortunately being much ameliorated through the efforts of the League of Nations and other agencies, so that it is now possible for an Englishman having frequent business in Paris to secure a passport and a French visé both of which are good for one year.

Customs Airdromes

As already noted, all aircraft making international journeys must, barring emergencies, land at a customs airdrome. These airdromes are located at Croydon and at Cricklewood for London and at Le Bourget for Paris, and incoming aircraft are handled and their contents examined by the customs officials very much as are ships at a port. Incidentally, several attempts at smuggling by aircraft have already been detected. The Croydon airdrome is especially remarkable for a system of landing lights which indicates the place to land and the wind direction. Lights below glass plates sunk flush with the surface of the field are arranged to form four pairs of parallel lines, and a single switch controls each pair of lines. The pilot is supposed to land between and parallel to the two lines which are switched on. The direction in which the wind is blowing along the lane thus defined is shown by the arrangement of the lights at the ends.

Status of Manufacturers

No consideration of the status of commercial aviation would be complete without some discussion of the relations and the interactions between the operating companies and the industry. In most instances the companies operating in Europe have been distinct from those making the aircraft, although there are several exceptions, such as the Handley-Page, Airco, Zeppelin, Rumpler, and Sablatnig. This separation leaves the manufacturer dependent for support on the sale of airplanes in the open market, assuming that there are no direct Government purchases, and it forces him not only to produce a type which will attract the traveler by air, but also to attract the operating companies, his potential customers, by making aircraft that are durable and economical and easy to repair, and by furnishing prompt service when anything goes wrong; factors some of which have not entered very largely into the calculations of airplane builders up to the present time.

The competition between manufacturers who must depend on a commercial market is certain to be bitter, for not even the greatest optimist can see any prospect of business that will support the number of producers now endeavoring to keep from the wall. The only hope for many of them, particularly those who have not the cap-

Side Guide & Gripper

ital to stand a long siege and to carry on an expensive publicity campaign throughout the world, lies in the growth of a demand for small airplanes from private individuals, for the demand for new machines from the air-transport services, numerous though these services are, is still very small. In a week of good weather 120 airplanes, most of which are of British manufacture, make the trip between England and the Continent. Allowing three trips per week for each airplane in active service, it can be assumed that 40 airplanes are engaged in cross-Channel transport. If the life of a commercial airplane flying an average of 10 hr. per week is taken as 18 months, the maintenance of the Anglo-Continental air services at their present strength would require the provision of only about 30 new airplanes a year, a small demand on which to rest an industry of the scope of that which grew up during the war. Although there is no doubt of the absolute necessity of increased reliability and durability, any increase in life unaccompanied by at least a corresponding increase in the extent of the commercial use of aircraft, will serve merely to aggravate the difficult situation in which the manufacturers now find themselves. Their only hope lies in constantly continuing expansion of the use of aircraft. For commercial flying to rest on its oars, satisfied with its existing position either now or at any future time, would clearly mean the virtual extirpation of the aircraft industry and be a national danger in that it would put a stop to the manufacture of an article essential for national defense.

Enclosed Cabins

Granting that there is to be bitter competition for such commercial business as exists, it remains to be seen what policy the producer should adopt and what features he should incorporate in his design to appeal to the purchaser. First, as to general layout, an enclosed cabin will be required in all cases in order that flights can be made with comfort to the passengers in all sorts of weather. The cabin must not, however, be made so airtight in the effort to secure warmth that the air inside can become bad. Several enclosed-cabin designs have been notorious offenders in this respect, and I believe that a large majority of the cases of airsickness which occur in straight cross-country flying are at least as chargeable to bad ventilation as to bumps and unsteady motion. The enclosure of the pilot's seat has not found favor in post-war European designs, with one or two exceptions, but there seems to be no very good reason for this, and the pilots who have tried it have found no difficulty in controlling the aircraft from inside the cabin. Another element having an important bearing on the comfort and convenience is the ease of access to the cabin and the freedom of movement inside. No airplane in which the passengers must make their entry by arising through the floor or descending through the roof has any commercial future, nor has any machine in which the cabin is crossed and re-crossed by bracing wires through which the occupants must thread their way. These things are much more important than attractive upholstery, figured walls and window curtains which have attracted so much attention in some recent productions. Fortunately few European machines of the last year offend in respect of accessibility and comfort. The necessity of omitting bracing wires and of putting in the side of the fuselage a door at least 4½ ft. high and without any wires or other members across it, imposes a fuselage constructed of either metal or veneer upon the designer of this type of aircraft, with the preference lying with the latter of these two materials.

Materials of Construction

Reliability requires a decided change from the present type of construction. All-metal construction is still regarded with grave suspicion outside of Germany, and even by many Germans, but metal is certain to be used to a constantly increasing extent in struts, spars, control surfaces and fuselages. In any case, fabric must go, in favor either of metal or of veneer. So long as the present rapid deterioration of the wing covering persists, the airplane cannot be regarded as a finished product for either commercial use or private ownership. It is my belief that the trend in non-military airplanes is toward veneer covering, such as is employed by Fokker on his latest products, rather than toward the metal covering made famous by Junkers and recently adopted in a different form by Short. Another material that has no proper place in large airplanes and has survived by reason of cheapness and simplicity of application, is the rubber in the shock-absorbers. Oleo and hydraulic gears in combination with relatively light steel springs have long been known and there is no reason why they should not have been used, especially on the largest commercial airplanes. Yet another point where change of material is necessary is in the propeller. The wooden propeller goes to pieces with amazing rapidity in rain or hail, and must be replaced by a screw of some more resistant material. Metal propellers are being experimented with extensively in Europe, and at least two, one of steel and one of aluminum, have reached the point of trial in flight. The bakelite propeller seems to fill the bill admirably, but it has not yet found its way across the Atlantic.

Number of Engines

The question of superiority between the single-engined and the multi-engined airplane has not yet been settled, and both types are in regular use. In order that a twin-engined airplane can maintain flight without losing altitude when one engine has been cut off, thus securing that added measure of safety against forced landings with which such craft are commonly credited, it must be very lightly loaded with full power and therefore be uneconomical as a vehicle for transporting useful load. When loaded for efficient commercial utilization it will certainly be impossible to stay in the air with the power reduced 50 per cent. A twin-engined machine which cannot hold the air with one engine cut off has obviously just twice as many chances of being forced to land by engine trouble as has the single-engined design, and a number of the operating companies are accordingly still clinging to the single unit. The easiest way around the twin-engine difficulty is to use light, high-efficiency engines of military type and not run them at full throttle under ordinary circumstances, thus prolonging their life and having a large potential power reserve in each engine to be called on in case of the failure of the other. This arrangement is preferable to the use of heavier and more reliable "commercial" engines run normally at full throttle only on twin-engined machines. The objection to the twin-engined airplane that has just been raised does not apply with nearly so much force when the number of engines is increased to three or four or more, and the commercial airplane of the future must be multi-engined unless it is to work over territory where a forced landing is possible at practically any point. Particularly if flights are to be made at night

Side Guide & Gripper

or over rough ground such as is found in the African colonies and on the road to the British dominions in the East, a multiplicity of engines will be essential. There is no tendency in any of the allied or neutral states to imitate the common German practice of keeping the powerplants central and gearing several engines together on a single large propeller, and this practice does not appear to offer any special advantages. The arrangement of engines in the Staaken giant is a much more promising development, as the distribution of weight along the span reduces enormously the stresses in the wing structure and makes lighter construction possible. This construction does, however, have the harmful effect of increasing the landing stresses, and such an airplane with cantilever wings, the Staaken is not a true cantilever job, could be landed only on a very smooth field where the several landing gears could be counted on to make contact simultaneously. The airplane with more than two groups of engines built into the wings must, therefore, to gain the full benefit of the distribution of weight, have enough powerplants and reliable enough ones that the possibility of a forced landing in a difficult field can simply be dismissed from the mind. Provision against forced landings in a large commercial aircraft should be so complete that provision for forced landings can be neglected. No naval architect attempts to design an ocean liner so that she can be run on the beach with impunity.

Marine Aircraft

With the total elimination of the forced landing as a factor, it will become safe to make overland journeys of reasonable length in flying boats, and it seems to me inevitable that much of the air traffic of the future will be by marine or amphibious aircraft, because of the ease of finding landing fields near great cities. Nearly all of the world's great centers have their business districts immediately adjacent to a frontage on sea, lake, or river, and the ability to take-off from and land at any waterfront would usually shorten the total time of a journey by at least ½ hr. At the present time the trips from the center of London out to Croydon and from Le Bourget into Paris by automobile consume almost half as much time as the whole journey from Croydon to Le Bourget by air. Already there has been much serious discussion, although no official action has been taken, of setting aside a strip of the Thames as a landing-place for aircraft, and it was presumably with an eye to the saving of time at the termini of intercity journeys that the Air Ministry undertook to encourage the design of amphibious aircraft by providing a special class for them in the civil aircraft competitions of the past summer.

Transferable Packing Cases

The cargo of an airplane is small enough so that it can often be completed with a single consignment, or at least with a group of shipments for the same destination, and a company has recently been formed in London to carry express exclusively, especially over long distances, packing the consignment in a case designed simply to drop into the cargo space of the airplane used and transferring this case and its contents bodily from one machine to another of similar type at the end of each stage of the flight, thus saving the time required to re-fuel and inspect the machine just finishing its flight and starting the express on its way again with scarcely more delay than was involved in a change of mounts and a transfer of the mail pouch in the pony express of the old West. Although this scheme may work out satisfactorily, there are no two points in the Eastern hemisphere between which it could be used so profitably as between our own Eastern and Western coasts.

The pictures which accompany this paper show a few of the types of airplane most commonly used in transport and "taxi" service.

CONFERENCE ON AERONAUTICAL SAFETY CODE

A CONFERENCE was held in Washington recently to consider the development of an aeronautical safety code for which the Bureau of Standards and the Society of Automotive Engineers have been designated as the joint sponsors by the American Engineering Standards Committee. This conference was attended by representatives of the War, Navy and Post Office Departments, the National Advisory Committee for Aeronautics, the National Safety Council, the Manufacturers' Aircraft Association and the Insurance Underwriters, as well as representatives of the two sponsors and the American Engineering Standards Committee.

It was the sense of this conference that a safety code ought to be developed without delay and that a committee should be formed at once to include representatives of all organizations interested in this subject as well as those which were present at the conference. Invitations have, consequently, been extended to various other organizations which are interested in the formulation of such a code.

BRITISH AND AMERICAN BANK DEPOSITS

BETWEEN June, 1914 and June, 1919, deposits in American banks increased about $19,000,000,000, or 88 per cent, while from December, 1914, to December, 1919, there was an increase of approximately £1,400,000,000 in British bank deposits, exactly the same percentage of increase as in the United States.—Bankers Trust Co.

Problems Involved in Developing Engine Gasoline Specifications[1]

By E. W. Dean[2]

ONE of the vital problems associated with the production, sale and utilization of engine gasoline is the development of practical specifications for quality and grade. The importance of this problem has been thoroughly recognized and the use of gasoline specifications is already an established practice. Large users, among which the Federal Government is a notable example, have adopted more or less complete sets of requirements for grades and quality of internal-combustion engine fuel. Transactions within the petroleum industry frequently involve specifications and last, but not least important, is the fact that a number of state and municipal legislative bodies have adopted or are considering the adoption of regulations controlling the quality of internal-combustion engine fuel dispensed to the general public.

The majority of the problems involved in the development of practical specifications for internal-combustion engine gasoline can be grouped in three general classes, as follows:

(1) The recognition of essential properties
(2) Definition of essential properties in terms of adequate laboratory tests
(3) The adoption of limits that express satisfactory quality in terms of the accepted laboratory tests

General Properties of Satisfactory Engine Gasoline

The following list of requirements is believed to indicate the general properties of satisfactory motor gasoline.

(1) Should not be unnecessarily dangerous in storage and handling and should not be subject to excessive evaporation losses
(2) Should not contain solid or non-combustible material
(3) Be free from constituents that corrode or injure the parts of the equipment in which it is stored or used
(4) Have a minimum content of constituents that tend to form solid or gummy deposits either in storage receptacles or in internal combustion engines
(5) Neither engine gasoline nor its products of combustion should possess markedly disagreeable odors
(6) Should have a properly limited and balanced range of volatility

There is no question as to the desirability of including in specifications a clause that will preclude the transportation, sale, and use of gasoline that is unnecessarily dangerous and that is subject to excessive losses in storage and handling. The accuracy and adequacy of the present vapor-pressure test[3] is, however, not above question and there is a clear necessity for its improvement. I understand that a modification of this test is being studied at the present time.

The presence of solid or non-combustible material can be determined by optical inspection of a properly taken sample. Gasoline should, of course, be perfectly transparent and homogeneous.

The problem of testing gasoline for corrosive constituents is one that cannot be adequately discussed since there is a notable lack of information regarding the causes and mechanism of this phenomenon and it is not believed that any or all of the present tests furnish conclusive evidence. The acidity test[4] is believed to offer a reliable means of detecting one type of corrosive constituent. The copper-dish evaporation test[5] is not satisfactory for the examination of internal-combustion engine gasoline, but a corrosion test under consideration by the American Society for Testing Materials and involving the same general principle can undoubtedly be used to detect another type of corrosive constituents. In general, however, it appears that the general problem of corrosive properties deserves more careful investigation than it has received.

One of the most troublesome phenomena in the operation of internal-combustion engines is the occurrence in cylinders and manifolds of carbon deposits. These are sometimes attributed to the use of lubricating oil of improper grade or unsatisfactory quality, but a fair proportion of evidence seems to indicate that the gasoline is either directly or indirectly the offending agent. It is by no means certain that the entire cause of the trouble is failure to effect proper dispersion of the fuel in the air mixture which goes into cylinders.

There is at present no satisfactory laboratory test indicating whether a particular sample of gasoline has an undue tendency to deposit solid material either in the manifolds and cylinders of internal-combustion engines or in storage tanks or pipe connections. The copper-dish evaporation test has a certain degree of application in this direction but it has been shown by some experiments[6] made in Bureau of Mines laboratories that it can be applied satisfactorily only to grades of gasoline, such as airplane gasoline, that can reasonably be expected to give no deposits. The test as at present outlined does not seem satisfactory to use with limits on the maximum allowable quantity of deposit.

It is believed that there is need of investigating this general problem and determining first whether there is need for a specific test for the property of forming solid deposits and second what this test should be. Work along this line has already been undertaken by the Bureau of Mines but the subject is so broad that it is believed that other research organizations can profitably

[1] Published with the permission of the Director of the Bureau of Mines. Abstract of a paper read before the 1921 annual meeting of the American Society for Testing Materials.

[2] S. M. S. A. E.—Petroleum chemist, Bureau of Mines Experiment Station, Pittsburgh.

[3] See report of the Chief Inspector of the Bureau of Mines on the Safe Transportation of Explosives and Other Dangerous Articles, February, 1916, pp. 27-30, and Bureau of Mines Technical Paper No. 214 entitled Motor Gasoline, Properties, Laboratory Methods of Testing and Practical Specifications, by E. W. Dean, pp. 26-27.

[4] See Bureau of Mines Technical Paper No. 214 entitled Motor Gasoline, Properties, Laboratory Methods of Testing and Practical Specifications, by E. W. Dean, p. 17.

[5] See report of Committee on Standardization of Petroleum Specifications, pp. 3-4.

[6] Results not yet published.

give it attention with the hope that the sum of the knowledge derived may yield a satisfactory answer.

Good odor is an important but, fortunately, not absolutely essential property of internal-combustion engine gasoline.

The important property of distillation range is one for which a satisfactory laboratory test has been developed and adopted. Some of the details of apparatus and procedure are still a fruitful subject for argument, but the tentative standard method of the American Society for Testing Materials[7] represents the agreement and compromises of men and organizations that have had the benefit of a very considerable amount of practical experience with the testing of gasoline.

Specification Limits

The most generally familiar set of gasoline specifications is that adopted by the Committee on Standardization of Petroleum Specifications and published in Bulletin No. 5 of that committee.[8] The specifications for engine gasoline include requirements for distillation ranges that place maximum limits on the temperatures read for the first drop, 20, 50 and 90-per cent marks and the dry point. The particular points selected for specification limits were carefully chosen and have not apparently been subject to particular criticism. The actual temperature limits for the first drop and 20 and 50-per cent points seem likewise to be reasonably satisfactory to both producers and consumers of internal-combustion engine gasoline. The limits for the 90-per cent mark and the dry point are the ones concerning which authorities and alleged authorities are in disagreement and which can be profitably discussed in the present connection.

A great number of refiners have discovered that they can produce gasoline which satisfies the dry-point clause with an ample margin of safety and still fails to meet the 90-per cent point requirement. This detail has been regarded as a serious flaw in the specifications and is so fruitful a source of argument that I take this occasion to point out the significance of this apparent lack of balance in the two limits. Determinations of the dry point have been and probably still are likely to involve a considerable possibility of disagreement between the results reported by different operators. The 90-per cent mark, on the other hand, is relatively easy to check. With this fact in view the members of the specifications committee thought it advisable to make the 90-per cent mark the effective upper distillation limit and use the end-point limit simply as insurance against careless or inefficient refining methods. The apparent discrepancy between these limits is, therefore, intentional and, on the basis of the evidence considered by the committee, justifiable.

[7]See Test D-21T of the American Society for Testing Materials.
[8]See The Journal, March, 1921, p. 219.

A more important difference of opinion concerns the actual limits, of which, as has just been indicated, the 90-per cent mark is usually the controlling one. A number of representatives of the refining industry have claimed that this is too low and therefore a detrimental influence on account of the present economic necessity of securing maximum yields of internal-combustion engine fuel from an inelastic supply of crude petroleum. Individual users are more or less inclined to the opinion that all present-day gasoline is unsatisfactory and that some products are worse than others. The most intelligent representatives of the consuming public are perhaps the men who design and supervise the building of internal-combustion engines and their majority opinion seems to be that gasoline meeting the present Government specifications may contain appreciable percentages of constituents that are not efficiently utilized by the average engine.

I cannot venture any opinion as to the relative merits of these opposing views and must, therefore, point out that the Government specification is actually a compromise and not the result of biased views or ignorance. The following suggestions are, however, offered as an indication of the basic principles that should cover the selection of limits for any specification that is likely to receive widespread recognition as a standard for the quality of internal-combustion engine gasoline:

(1) Specification limits should be selected as an agreement or at least a compromise between the views and thoroughly representative groups of authorities from the producers and the users
(2) Reasonable uniformity should be maintained in the quality of the gasoline produced by different refining companies and in different parts of the country. The influence of the law of supply and demand should be reflected in the price of the commodity rather than its quality
(3) Radical changes in the general quality of internal combustion engine gasoline should, if possible, be agreed on and announced a reasonable length of time in advance of the date when the modification is to be made effective. This does not concern the normal seasonal variation in quality but rather such changes as are likely to affect the efficiency of the average existing engine. If such an arrangement could be effected it would be possible for automotive engineers to design and build engines to "fit" a known quality of gasoline and also permit the development of supplementary devices to improve the operating efficiency of engines already in use

These suggestions obviously indicate the necessity of cooperation between representatives of the producers and consumers. Such cooperative effort is already being organized and, needless to say, the Bureau of Mines commends all possible activity in its behalf.

Merits of Different Splices for Airplane Wing Beams

By H. D. FRARY[1] *Illustrated with* DRAWING

EARLY in the war the great demand for airplane spruce led to a shortage of clear, straight-grained pieces long enough for airplane wing beams. This shortage made it necessary to allow splicing; consequently, early in 1918, specifications for several different types of splices were drawn up by the airplane engineering division of the Signal Corps. To determine the relative merits of these and other types of splice for wing beams, the United States Forest Products Laboratory at Madison, Wis., began in March, 1918, the tests described.

As the tests progressed, other problems developed or were suggested from various sources. At first the investigation was confined to solid and two-piece laminated beams, such as were being used in the actual construction of airplanes; but when the Air Service decided to investigate the built-up three-piece I and box types, Nos. 21 to 35, with a view to putting them into production, the Laboratory began a study of splices in these types of beam also. Altogether, the results here presented represent nearly a year's work, comprising tests of 670 spliced beams of 51 different kinds, together with 345 matched unspliced beams. The results obtained are by no means the last word on splices in wing beams, as many points have developed that require further investigation, but the tests have established certain conclusions of considerable importance.

MATERIAL AND CONSTRUCTION OF BEAM

All the beams were made in the Laboratory carpenter shop of kiln-dried Douglas fir and Sitka spruce. Results of tests on any beams found to be of stock unsuitable for airplane use were rejected from the averages and from the tabulated results. Certified hide glue which was spread by hand was used and hand clamps were employed to hold the parts together. The gluing on the first set of beams, namely, the Douglas fir beams of types Nos. 3, 10, 11, 13, 14, 15, 16, 19 and 20, was probably not quite so expertly done as was that on other beams made up later.

To determine the efficiency of a splice an unspliced beam was always matched to each spliced beam and to compare the relative efficiencies of two different types of splice each spliced beam of the one type was always matched to the corresponding spliced beam of the other type. This matching was accomplished by cutting the beams side by side from the same plank.

The construction of the spliced beams of each type is clearly shown in drawings Nos. 1 to 35 of the accompanying illustration. Solid and two-piece wing beams are usually routed out to form an I-section, but for greater strength it is customary to leave the beams unrouted at the splice. For test purposes, however, the beams of types Nos. 1 to 20, both spliced and unspliced, were made rectangular in section throughout. Consequently, the efficiencies of splices are based on the unrouted unspliced beam.

The beams were tested in cross-bending with loads at the third-points,[2] the span being 60 in. for types Nos. 1 to 20, and 72 in. for types Nos. 21 to 35. The splices being at the center were subjected to the maximum moment but not to shear stress. Following the beam tests, specimens were cut from each beam for tests in compression parallel to the grain and for specific gravity and moisture determinations. The purpose of these tests was to check up the matching and to give a measure of the quality of material. A summary of the principal data and results is given in Table 1 with references to the various splices.

KIND AND PLANE OF SCARF

Obviously, splices should be of comparatively simple design and easy to make. The greater the degree of skill required and the more complicated the process, the higher the labor costs and the more danger of poor workmanship with a resulting lack of reliability. Probably in a large measure for these reasons, the plain sloped scarf, with or without dowels or bolts, has been very generally adopted for wing-beam splices. Of the 35 types discussed here, 32 are based on the plain sloped scarf. Three other kinds of scarf, types Nos. 9, 10 and 19, were tested.

Type No. 9 has a sloping scarf like type No. 3, but with two three-ply plywood splines inserted. If the results for these two types in Douglas fir are compared it is seen that the efficiency of the splice with splines was consistently lower than that of the plain splice, the averages being 54.6 and 73.0 per cent respectively. Apparently, cutting out the beam for the insertion of the splines weakens it considerably more than the splines strengthen it.

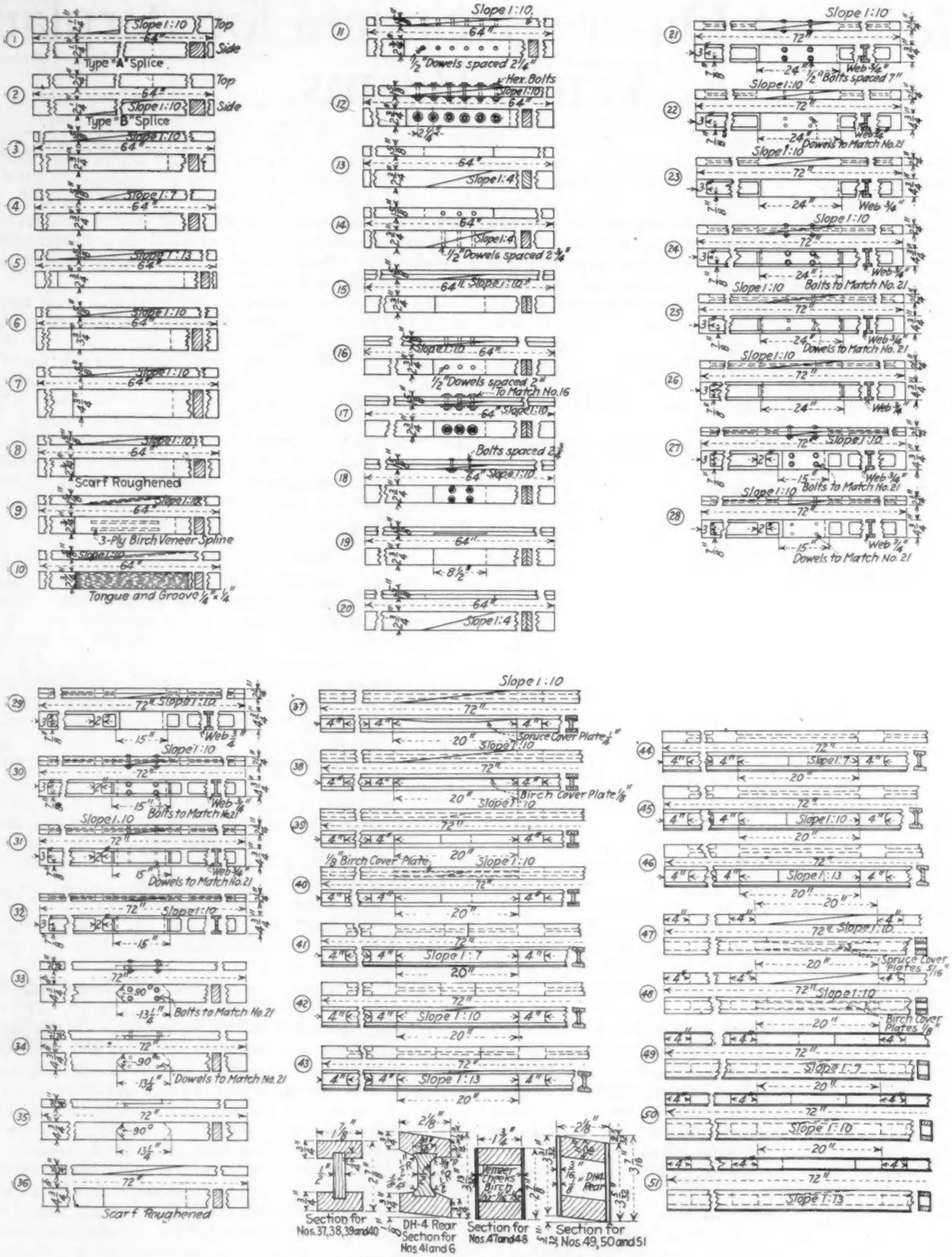
Type No. 10 is a splice consisting of close-fitting ¼-in. tongue-and-groove joints at a slope of 1 in 10. The average efficiency obtained was 75.9 per cent. This is slightly greater than that of the plain splice of the same slope, No. 3, and the same material, Douglas fir, which was 73 per cent, but the minimum values are practically the same. As a matter of fact, the workmanship on type No. 9 was probably somewhat better than on the fir beams of type No. 3, as already stated. Apparently this tongue-and-groove splice is no stronger than the plain splice, No. 3, and it is, of course, more difficult to make.

The third type of splice other than a plain sloped scarf is the half-lap scarf illustrated for a two-piece beam in type No. 19. In this splice the principal glued surface is parallel to the sides of the beam. If the efficiency of No. 19 is compared with that of No. 15, it is seen that this type is decidedly inferior to the plain sloped scarf of the latter type.

The conclusion from these tests on different kinds of

[1] Engineer, forest products laboratory, Department of Agriculture, Madison, Wis.

[2] A few tests made to determine the difference in strength of a splice under third-point and center loading disclosed no variation whatever.


Type "A" Splice
Type "B" Splice
Scarf Roughened
3-Ply Birch Veneer Spline
Tongue and Groove 1/4 x 1/4
1/2" Dowels spaced 2 1/4"
Hex. Bolts
1/2" Dowels spaced 2 3/4"
1/2" Dowels spaced 2"
To Match No. 16
Bolts spaced 2"
1/2" Bolts spaced 7"
Dowels to Match No. 21
Bolts to Match No. 21
Spruce Cover Plate 1/4"
Birch Cover Plate 1/8"
1/8" Birch Cover Plate
Spruce Cover Plates 5/16"
Birch Cover Plates 1/8"
Section for Nos. 37, 38, 39 and 40
DH-4 Rear Section for Nos. 41 and 6
Section for Nos. 47 and 48
Section for Nos. 49, 50 and 51

VARIOUS SPLICES AND BEAMS TESTED

The Numbers in the Circles Opposite Each Splice or Beam Section Correspond to Those in the First Column of Table 1

TABLE 1—TESTS OF AIRPLANE WING BEAM SPLICES

One and Two-Piece Rectangular Beams

Type No.	Pairs of Matched Beams[3]	Material	Efficiency Ratio of Spliced to Unspliced Beams, per cent			Length of Splice, in.	Glue Area of Splice, sq. in.	Relative Efficiency, per cent				Routing and Filler Blocks at Splices	Location of Splice	Slope of Splice	Splice Failures, per cent
			Minimum	Maximum	Average			Compared to Type No.	Minimum	Maximum	Average				
1	.....	Spruce	.....	.....	.....	22.5	50.8	...	.....	.....	.....				
2	10	Spruce	.....	.....	.....	22.5	50.8	1	57.1	209.5	122.0				
3	6	Fir	49.5	88.0	73.0	16.2	44.9	...	.....	.....	.....				
	10	Spruce	70.2	103.8	91.3	16.2	44.9	...	.....	.....	.....				
4	8	Spruce	.....	.....	.....	11.4	31.6	3	61.0	121.5	88.8				
5	8	Spruce	.....	.....	.....	21.1	58.3	3	87.7	121.7	100.4				
6	10	Spruce	82.4	127.3	102.6	16.2	61.2	...	.....	.....	.....				
7	10	Spruce	71.9	111.6	95.6	16.2	77.6	...	.....	.....	.....				
8	10	Spruce	.....	.....	.....	16.2	44.9	3	76.8	115.8	99.7				
9	8	Fir	41.9	59.5	54.6	16.2	68.3	...	.....	.....	.....				
10	10	Fir	50.0	100.0	75.9	16.2	85.7	...	.....	.....	.....				
11	9	Fir	72.5	107.0	86.8	16.2	44.9	...	.....	.....	.....				
	7	Fir	.....	.....	.....	16.2	44.9	3	78.5	119.1	93.4				
	10	Fir	.....	.....	.....	16.2	44.9	3	72.7	159.0	110.4				
	9	Spruce	54.5	103.5	88.3	16.2	44.9	...	.....	.....	.....				
	9	Spruce	.....	.....	.....	16.2	44.9	3	68.4	117.8	97.5				
12	10	Spruce	78.6	116.1	92.6	16.2	44.9	...	.....	.....	.....				
	10	Spruce	.....	.....	.....	16.2	44.9	3	78.6	128.5	102.1				
13	7	Fir	17.0	53.1	33.7	11.0	18.4	3	33.3	57.1	46.8				
14	9	Fir	19.6	61.4	38.6	11.0	18.4	...	.....	.....	.....				
15	10	Fir	77.7	105.5	90.0	8.1	22.4	...	.....	.....	.....				
	9	Spruce	71.5	114.0	93.2	8.1	22.4	...	.....	.....	.....				
16	10	Fir	72.0	123.5	100.2	8.1	22.4	...	.....	.....	.....				
	6	Fir	.....	.....	.....	8.1	22.4	15	75.2	165.6	110.8				
	10	Fir	.....	.....	.....	8.1	22.4	15	64.2	125.0	96.0				
	9	Spruce	66.2	104.6	83.0	8.1	22.4	...	.....	.....	.....				
	10	Spruce	.....	.....	.....	8.1	22.4	15	71.2	121.8	90.6				
17	9	Spruce	54.0	107.8	86.4	8.1	22.4	...	.....	.....	.....				
	10	Spruce	.....	.....	.....	8.1	22.4	15	54.0	131.3	93.5				
18	6	Fir	61.5	82.7	72.9	8.1	22.4	...	.....	.....	.....				
	9	Fir	59.5	81.5	72.9	8.1	22.4	...	.....	.....	.....				
19	9	Fir	58.8	98.7	81.0	8.5	23.4	...	.....	.....	.....				
20	10	Fir	39.1	86.5	66.6	11.0	9.2	...	.....	.....	.....				
Navy Beams[4]															
21	3	Spruce	72.5	96.0	84.3	22.5	107.3	...	.....	.....	.....	Unrouted			
	2	Spruce	87.5	108.0	97.8	22.5	107.3	...	.....	.....	.....	Unrouted			
22	5	Spruce	79.5	114.6	97.2	22.5	107.3	...	.....	.....	.....	Unrouted			
23	5	Spruce	93.8	146.8	112.6	22.5	107.3	...	.....	.....	.....	Unrouted			
24	5	Spruce	79.5	126.3	93.8	22.5	62.1	...	.....	.....	.....	Routed, blocks glued in			
25	5	Spruce	88.4	109.5	97.7	22.5	62.1	...	.....	.....	.....	Routed, blocks glued in			
26	4	Spruce	75.7	126.0	100.0	22.5	62.1	...	.....	.....	.....	Routed, blocks glued in			
27	3	Spruce	104.4	145.2	119.9	11.2	53.6	...	.....	.....	.....	Unrouted			
28	3	Spruce	97.2	116.0	109.3	11.2	53.6	...	.....	.....	.....	Unrouted			
29	5	Spruce	71.9	105.6	87.4	11.2	53.6	...	.....	.....	.....	Unrouted			
30	4	Spruce	73.2	102.3	93.6	11.2	53.6	...	.....	.....	.....	Routed, blocks glued in			
31	5	Spruce	99.0	109.8	104.9	11.2	53.6	...	.....	.....	.....	Routed, blocks glued in			
32	5	Spruce	81.5	100.0	93.4	11.2	53.6	...	.....	.....	.....	Routed, blocks glued in			
33	5	Spruce	33.6	43.9	39.5	13.2	52.7	...	.....	.....	.....	Unrouted			
34	5	Spruce	31.7	53.0	38.2	13.2	52.7	...	.....	.....	.....	Unrouted			
35	5	Spruce	28.9	51.6	36.5	13.2	52.7	...	.....	.....	.....	Unrouted			
36[5]	5	Spruce	69.0	119.3	90.2	22.5	107.3	...	.....	.....	.....	Unrouted			
	5	Fir	87.2	100.0	93.4	22.5	107.3	...	.....	.....	.....	Unrouted			
Built-up Beams															
37	6[6]	Spruce	105.2	125.0	112.2	...	.....	...	.....	.....	.....		Flange	1 in 10	17
38	7[6]	Spruce	93.8	120.0	105.5	...	.....	...	.....	.....	.....		Flange	1 in 10	14
39	5	Spruce	100.0	104.1	102.3	...	.....	...	.....	.....	.....		Web	1 in 10	0
40	5	Spruce	93.0	109.6	101.2	...	.....	...	.....	.....	.....		Web	1 in 10	0
41	9[6]	Spruce	71.4	103.4	94.3	...	.....	...	.....	.....	.....		Tension Flange	1 in 7	67
42	10	Spruce	87.9	111.9	97.0	...	.....	...	.....	.....	.....		Tension Flange	1 in 10	33
43	10	Spruce	80.6	108.3	97.6	...	.....	...	.....	.....	.....		Tension Flange	1 in 13	0
44	10	Spruce	79.4	110.7	94.2	...	.....	...	.....	.....	.....		Web	1 in 7	0
45	10	Spruce	94.4	113.1	99.2	...	.....	...	.....	.....	.....		Web	1 in 10	0
46	10	Spruce	89.5	120.0	101.0	...	.....	...	.....	.....	.....		Web	1 in 13	0
47	5	Spruce[7]	85.9	138.1	103.7	...	.....	...	.....	.....	.....		Tension Flange	1 in 10	40
	5	Spruce[7]	71.5	136.3	102.2	...	.....	...	.....	.....	.....		Compression Flange	1 in 10	20
48	6	Spruce[7]	63.4	124.0	89.5	...	.....	...	.....	.....	.....		Tension Flange	1 in 10	50
	4	Spruce[7]	67.3	104.9	81.9	...	.....	...	.....	.....	.....		Compression Flange	1 in 10	50
49	9	Spruce[7]	44.0	122.8	77.6	...	.....	...	.....	.....	.....		Tension Flange	1 in 7	78
50	10	Spruce[7]	53.1	117.8	92.6	...	.....	...	.....	.....	.....		Tension Flange	1 in 10	30
51	10	Spruce[7]	85.0	159.3	104.5	...	.....	...	.....	.....	.....		Tension Flange	1 in 13	20

See page 136 for footnotes.

scarf is that the general practice of using the plain sloped scarf is justified, since none of the other types or modifications tested gave better results, and all are more difficult to make.

Shall the splice be across the top of the beam or across the side? That is, shall the plane of the scarf be perpendicular to the top or to the side face of the beam? To compare these two types, called for brevity type A and type B, respectively, 20 beams in matched pairs like Nos. 1 and 2 were made and tested. The beams were square and, aside from the splices, as much alike as they could be made. The results of the tests indicated that the splice across the side was more efficient than the splice across the top, the average relative efficiency being 122 per cent. There were, however, three erratic values, two high and one low. The beams from which these erratic ratios were derived were carefully inspected without finding any justification for rejecting the results. The omission of the percentages derived from these three would give an average percentage of 107.6. The fact that 9 out of the 10 pairs, or, if the three erratic values be rejected, 7 out of 7 pairs of beams gave percentages in excess of 100 was a further indication of the superiority of the type B over the type A splice in square beams. The data was not regarded, however, as furnishing a sufficient basis for a statement of the amount of this superiority.

To obtain more conclusive evidence on this point, further tests of these two types of splice were made. Sixty additional beams like the above were made up, matched in sets of 3, 20 unspliced, 20 spliced across the top and 20 spliced across the side. Special care was exercised in selecting the material and in making up these beams. The two spliced beams of each matched set were cut side by side and so as to be from the same annual rings. The unspliced beam was cut next to one of the spliced beams. The two spliced beams of each set were made by the same man and glued at the same time, so as to eliminate the personal equation and any difference in different mixes of glue. The three beams of each set were tested with annual rings in the same direction, and the direction of rings in the different sets was varied, as many with rings horizontal as vertical, to eliminate any possible influence of the direction of the rings upon the average results.

The results of these tests, contrary to expectations based on the tests previously made, gave almost exactly the same average efficiencies for the two types; that is, the relative efficiency was 100 per cent. One very interesting fact seemed to be shown by these tests, namely, that the direction of the annual rings has an effect upon the efficiency of the splices. Of the eight sets of beams in which the annual rings were horizontal during the test, the results from six sets showed higher efficiencies for the type A splice than for the type B splice, and the average relative efficiency, type B divided by type A, was 95 per cent. On the other hand, of seven sets of beams with rings vertical, none showed a greater efficiency for type A than for type B, and the average relative efficiency was 107 per cent. Apparently, a splice is somewhat stronger when it cuts across a tangential face than when it cuts across a radial face of a beam. An examination of the 10 pairs of beams previously tested showed that the superiority of type B over type A in these tests could be partly, if not wholly, accounted for by the direction of the rings. The conclusion is reached, therefore, that in square beams splices across the top and across the side are equally efficient.

With rectangular beams it is somewhat different. In a square beam, a type A splice and a type B splice of the same slope have the same glued area and the same length. In a rectangular beam, splices of types A and B, if of equal slope, have the same glued area but are not the same in length; for example, in a beam twice as high as it is wide, the type B splice across the side would be twice as long as the type A splice across the top. Presumably the shorter splice is preferable. The question then arises: If splices of an equal length in rectangular beams are assumed, which is the more efficient, type A or type B? Since the two types are equally efficient in square beams it is natural to expect that in rectangular beams the splice which has the greater glued area will be the more efficient. In other words the splice should cut across the narrower face of the beam; that is, type A or B should be used, according as the height-width ratio is greater or less than unity.

A check on this conclusion is afforded by a comparison of the efficiencies of splices Nos. 4 and 13 with No. 3. The scarf of splice No. 4, type A with a slope of 1 in 7, has practically the same length as that of No. 13, type B with a slope of 1 in 4. No. 4 was 89 per cent as strong as No. 3, while No. 13 was only 50 per cent as strong; that is, the type A splice was much superior to the type B. This is as would be expected, since the height-width ratio of these beams is greater than unity. A further check is obtained by comparing two two-piece beams No. 20 with a type B splice with No. 15 having a type A. Here the length of scarf is in favor of No. 20; nevertheless, the splice was only 66.6/90 or 74 per cent as strong as No. 15. As practically all wing beams are higher than they are wide, it may be stated as a general rule, to which there may be an occasional exception, that solid and two-piece wing beams should be spliced diagonally across the top of the beam, that is, the plane of the scarf should be perpendicular to the top of the beam.

The question now arises: What is the best slope for the scarf of a plain type A splice? If splices Nos. 4 and 5 are compared with No. 3, it is seen that No. 4 with a slope of 1 in 7 was 11 per cent weaker than No. 3 having a slope of 1 in 10 and No. 5 with a slope of 1 in 13 was practically the same as No. 3 in strength. We conclude that for spruce beams with high-grade glue and good gluing the efficiency is increased very little by using smaller slopes than 1 in 10.

Splices Nos. 6 and 7 having a slope of 1 in 10 and the plane of the splice vertical were tested to get information

FOOTNOTES FOR TABLE 1 ON PAGE 135

[3] In every case 10 pairs of matched beams were made and tested, but some beams had to be rejected on account of defective material.

[4] All unspliced beams except the first three of type No. 21 were routed in the middle section as well as in the end sections, but these three were left unrouted in the middle section by mistake. The beams to match these spliced beams were like the latter in dimensions and routing, but for types Nos. 29 to 32 the unspliced beams were, of course, routed in the middle section. Five pairs of beams were tested for each type of splice, but some had to be rejected on account of defective material. With the exception of types Nos. 33 to 36 these tests do not give the real efficiencies of the splices because most of the beams failed in the routed part outside the splice.

[5] The efficiency ratio for type No. 36 is that of the roughened to the smooth scarf instead of the ratio of the spliced to the unspliced beam as in all other cases.

[6] Ten pairs of beams were tested, but some of the results were rejected on account of defective material.

[7] The checks of these beams were birch-poplar-birch plywood.

concerning the difference in the efficiency with a variation in the height-width ratio. These can be compared with types Nos. 1 and 3. The ratios of height to width for splices Nos. 1, 3, 6 and 7 are respectively 1.0, 1.7, 2.3, and 2.9 and the corresponding average efficiencies obtained for Sitka spruce are 99.6, 91.3, 102.6 and 95.6 per cent. The third efficiency is evidently too high, for it indicates that the spliced beams were slightly stronger than the matched unspliced ones, although three of the spliced beams showed glue failures under test. The first efficiency also seems too high. The figures show no consistent relation and a larger number of tests would be necessary to determine whether there really is any relation between the height-width ratio and the efficiency.

There seems to be a marked difference of opinion in regard to the effect of roughening the scarf of a splice; many practical men insist that this treatment increases the strength of the splice materially. To test this point, 10 spruce beams, spliced like No. 3 were matched to 10 beams spliced in the same way except that the scarfs were roughened with a toothing plane, No. 8. The average relative efficiency obtained by dividing the roughened splice by the smooth is 99.7 per cent. Corresponding tests on 10 pairs of beams of larger size, 2¼ x 4¾ x 76 in., half spruce and half fir, gave average relative efficiencies of 90.2 and 93.4 per cent respectively. Evidently, roughening the scarf of a splice does not increase its strength. These results agree very well with tests recently made at the Laboratory on the shearing strength of scratched or roughened glued joints in hard maple In these tests also the scratched joints were slightly weaker, on the average 2.5 per cent, than the smooth joints.

Value of Dowels and Bolts

In making doweled and bolted splices, a plain splice was first made in each beam. After the glue had set, the holes were bored and dowels were glued in or bolts were inserted. Dowels were of the same material as the beams. Bolts were tightened down as much as possible without injuring the wood. Since the boring of holes undoubtedly weakens a beam, this question arises: Do the dowels or bolts strengthen the beam more than it is weakened by the holes?

The evidence on the effect of dowels in one-piece beams, as shown in Table 1, is somewhat conflicting. The first tests gave, for the efficiency of the doweled splice in Douglas fir, 86.8 per cent as against 73 per cent for the undoweled splice, or 119 per cent for the relative efficiency of doweling. Later tests on fir gave 93.4 per cent and 110.4 per cent for the relative efficiency of doweling. The average of the three is about 108 per cent; that is, the evidence is in favor of the doweled splice. In Sitka spruce, on the other hand, the doweled splice was slightly less efficient, 97.5 per cent, than the plain splice. On a type B splice, Nos. 13 and 14, the efficiency of dowels was 38.6 per cent as against 33.7 per cent without, a slight difference in favor of the dowels. From all this evidence, even though it is somewhat conflicting, it can safely be concluded that the influence of dowels on the efficiency of splices in one-piece beams is small. The results from tests of splice No. 12 with bolts indicate that the same conclusion may be drawn in regard to bolted splices in one-piece beams.

In the two-piece beams, also, the evidence for and against dowels is conflicting. In fir, the first series of tests on doweled splices, when compared with results for the spliced beams without dowels, gives 100.2/90 or 111.3 per cent for the relative efficiency of doweling. The corresponding relative efficiencies for the other two series of tests with fir are 110.8 and 96 per cent, giving an average of 106 per cent. On the other hand, the tests with spruce give only 90.6 per cent relative efficiency. The evidence seems to indicate that the dowels added to the strength of two-piece fir beams but reduced the strength of similar spruce beams. This, as well as the somewhat similar results in one-piece beams, may be due to the fact that the glue does not hold so well in Douglas fir as in Sitka spruce, and that the dowels are brought into play to a greater extent in the fir beams.

Nos. 17 and 18 are bolted splices in two-piece beams. In No. 17 the bolts were located along the neutral surface in the same way as the dowels in No. 16 and were of the same size, ½ in. In No. 18 the bolts were ⅜ in. and not on the neutral surface. No. 17 was Sitka spruce and No. 18 Douglas fir. Both types show efficiencies considerably below those of the plain splice. Evidently the bolts weakened the splice instead of strengthening it. The particularly poor showing for No. 18 is probably due to the fact that failure often started by crushing or splitting of the wood at the bolt-holes on the compression side. As the bolts are comparatively incompressible, a distortion of the stresses in their neighborhood occurs.

The most common argument in favor of dowels and bolts is that, if the glue fails, the dowels or bolts will hold the beam together, or at least prevent a sudden collapse of the beam without warning. If the dowels or the bolts will hold a wing beam together long enough after the glue fails for the aviator to reach the ground in safety, their use is more than justified. To obtain data on this point, five Sitka spruce beams of each of the types Nos. 11, 12, 15, 16 and 17, were made up exactly like the beams previously tested except that no glue was put on the scarf of the splice. They were matched to unspliced beams as in previous tests and thus the efficiencies of the doweled and bolted splices without glue on the scarfs were obtained. The results are summarized in Table 2.

TABLE 2—COMPARATIVE EFFICIENCIES OF BOLTED AND DOWELED SPLICES

Beam	Type of Splice	Type No.	Efficiency, per cent Minimum	Maximum	Average
One-Piece	Doweled	11	8.8	17.1	13.1
One-Piece	Bolted	12	17.2	21.6	18.7
Two-Piece	Plain	15	27.8	60.1	46.0
Two-Piece	Doweled	16	47.1	64.1	58.0
Two-Piece	Bolted	17	54.2	75.0	69.0

Evidently, in one-piece beams, a doweled or bolted splice without glue on the scarf has very little strength, less than 20 per cent of that of the unspliced beam. In two-piece beams with a splice in one lamination, dowels or bolts keep up the strength to 60 or 70 per cent of that of the unspliced beam.

It is evident that dowels and bolts do not come into action to any great extent unless the glue fails in the splice; that is, they do not aid the glue or prevent glue failures. If the glue fails, the dowels or bolts are at once brought into play. Acting alone, the bolts contribute more strength than the dowels, but in either case the contribution is comparatively small. In one-piece beams this small contribution can be of no practical value if the glue fails under load for the beam will collapse immediately in spite of dowels or bolts, but in two-piece beams the added strength due to the dowels or bolts, after the glue has failed under load, may be sufficient to hold the beam together and hence, to justify their use. Moreover, if the splice in a wing beam is at a point of contraflexure

or low moment and the glue should fail entirely because of its poor quality, or the action of moisture, or for some other reason, the dowels or bolts would doubtless be strong enough to hold the two parts together and thus make their use advisable.

Although the results, on the whole, seem to favor bolts over dowels, nevertheless, dowels are preferable for the following reasons:

(1) The bolts are so hard and unyielding that the continual working and straining of the parts soon crushes the wood around them and makes them worse than useless. For the same reason wooden trenails are preferred to bolts or spikes in shipbuilding
(2) The dowels, on the other hand, will bend and give as the parts are stressed without injuring them.
(3) Shrinking of the wood on account of its drying out may cause the bolts to become loose and hence of little value
(4) The initial tightening of the bolts or subsequent tightening on account of swelling of the wood is likely to crush the wood and reduce its strength
(5) Bolts add to the weight

Splices in Three-Piece I-Beams

Splices Nos. 21, 22, 25 and 27 were in the flanges of three-piece I-beams. In the first two the type A splice was used and reinforced with cover-plates. These cover-plates made the spliced beams stronger than the unspliced ones; consequently, they were not used in later tests. It was also decided to use the type B splice instead of type A, since the height of the flange is less than the width. In Nos. 25 to 27, then, the type B splice was used without reinforcement of any kind. These beams were tested to determine the best slope for such a splice, the slopes used being 1 in 7, 1 in 10, and 1 in 13 respectively. If the results shown in Table 1 are compared, it will be seen that the average efficiencies developed for splices with slopes 1 in 10 and 1 in 13 were practically the same, 97 per cent; while the efficiency for a slope of 1 in 7 was somewhat less. The conclusion is that with good gluing a slope of 1 in 10 is sufficient to develop practically the full strength of the section.

Splices Nos. 23, 24 and 28 to 30 were type A splices in the webs of three-piece I-beams. In none of these beams was any sign of a splice failure observed. Evidently, a splice in the web is not subjected to a very severe strain. Results for Nos. 23 and 24 showed that cover-plates were unnecessary. Nos. 28 to 30 compared slopes of 1 in 7, 1 in 10, and 1 in 13. Although no glue failure occurred in any splice, type No. 28 having a slope of 1 in 7 was not quite so efficient as types Nos. 29 and 30, the ratios being 94, 99, and 101 per cent respectively. Here, too, the splice with a slope of 1 in 10 seems to develop the full strength of the section.

Drawings Nos. 31 to 35 illustrate five types of splice in box beams. Tests of the first two showed, as would be expected, that a splice in the tension flange was less efficient, or at least not more efficient, than one in the compression flange. For this reason the beams were placed with the splices on the tension side in the other tests. Also, as in the case of the three-piece I-beams, the type B splice was adopted and cover-plates were abandoned. Nos. 33 to 35 were then tested to determine the best slope for a type B splice in the tension flange without cover-plates or other reinforcement. The efficiency ratios obtained for slopes of 1 in 7, 1 in 10 and 1 in 13 were 77.6, 92.6, and 104.5 per cent respectively. Evidently, the slope required in such a splice to develop the full strength of the section is between 1 in 10 and 1 in 13.

Summary of Results

(1) Of the four different kinds of scarf tested, the plain sloped scarf is the best, both from the standpoint of efficiency and of ease of manufacture
(2) For such a splice the following conclusions are reached: (*a*) In solid beams and parts of built-up beams in which the height is less than the width, as, for example, the flanges of three-piece I- and box-beams, the plane of the scarf should be perpendicular to the plane of bending; that is, the scarf should be diagonally across the side. (*b*) In beams or parts of beams in which the height is greater than the width, including practically all solid wing beams, two-piece laminated beams, and webs of three-piece I-beams, the plane of the scarf should be vertical; that is, the scarf should be diagonally across the top. (*c*) In beams with the height equal to the width either type of splice can be used
(3) For such splices in Sitka spruce beams with high-grade glue and good gluing, the tests show that a slope of 1 in 10 is sufficient to develop practically the full strength of the section. The average efficiency obtained for this splice in one-piece beams having a rectangular cross-section of 1⅝ x 2¾ in. without reinforcement of any kind, was about 91 per cent
(4) Roughening the scarf does not increase the efficiency of a splice
(5) Dowels or bolts do not materially affect the efficiency of a well-made splice; they do not come into action to any extent until the glue fails. If this occurs in the splice in a one-piece beam, dowels or bolts ordinarily will not prevent an immediate collapse of the beam, unless the joint is subjected to a moment less than 20 per cent of the maximum moment which the unspliced beam will withstand. In the two-piece laminated beam, however, with a splice in one lamination, dowels or bolts may keep up the strength enough to prevent collapse if the moment at the joint is not more than about 65 per cent of the maximum moment which the unspliced beam will withstand. Although results of tests are slightly better for splices with bolts than for those with dowels, the latter are, as a rule, preferable in practice

America as a World Power

By JOHN PAUL GOODE[1] CHICAGO MEETING ADDRESS

IN President Washington's farewell address of September, 1796, the fear of entangling alliances was written indelibly into our foreign policy. Quoting from this memorable document:

> Against the wiles of foreign influence I conjure you to believe me, fellow-citizens, the jealousy of a free people ought to be constantly awake. History and experience prove that foreign influence is one of the most baneful foes of republican government. The great rule of conduct for us in regard to foreign nations is, in extending our commercial relations, to have with them as little political connection as possible.

The wisdom of this solemn counsel has been conceded by all our statesmen down to the recent emergency. Washington saw clearly our weakness and our isolation, for we were small and poor 124 years ago.

Let us see how small and poor we were and what has happened since that time. In 1800 we had a population of 5⅓ million. We were a small nation. Russia, the greatest nation, had a population of 37,000,000; France, 27,000,000; Germany, 25,000,000; Austria-Hungary, 24,000,000; Italy, 18,000,000; Great Britain, 16,000,000; and Spain, 11,000,000. With only 5⅓ million we were on a par with Norway, Sweden and Portugal. We were a long way off; it required 30 days to cross the ocean 100 years ago. This population of ours was scattered along the Atlantic coast for 1000 miles; we had only penetrated the Appalachian barrier slightly in three places. We were small and weak and poor, and Washington was very wise in advising us as he did. The country's area then was only a little over 800,000 sq. miles. We nearly doubled it in 1803 by the Louisiana Purchase. We have added more land since then until, when the war came, we had an area of 3,027,000 sq. miles and had become one of the world's great nations measured in area occupied.

We have grown in many other ways. Starting with 5⅓ million, we crossed the 100,000,000 mark in 1914. Only one of the great nations could compare with us in the rate of growth; Russia in Europe had 133,000,000 people in 1910. Of the other great nations of 100 years ago, France never reached a population of 40,000,000 until since the armistice. The United Kingdom has grown commendably; so has Germany, but not to compare with us. We have come to be one of the world's great nations, and yet we are still on the Atlantic margin of our continent. The western half of our country is still largely unoccupied. We still are facing the East across the narrow sea, and for good reasons. Comparing ourselves with the rest of the world in population, China has something over 400,000,000; India, 320,000,000; and Russia as it was in 1914, 207,000,000. We are fourth in the world in population, which runs now to over 110,000,000. We are not in the class of Norway, Sweden and Portugal now.

SHIPBUILDING AND FOREIGN COMMERCE

In several other ways we have grown great. One of the best ways of measuring international importance today is to consider foreign commerce. The great nations trade across the seas, so we may look at the growth of our merchant marine as part of our study. We had less than 1,000,000 tons of shipping in 1800, and grew very slowly for three decades. Then we increased very commendably and reached a peak of over 5,000,000 tons in 1855. The Civil War reduced that, but we had grown to something like 8,000,000 tons when the war began. In all this century Great Britain has stood high, with twice the tonnage we had in 1800, and had risen until, just before the war began, she had 22,000,000 tons of merchant shipping on the sea. Only once in the century was Great Britain's proud place challenged, and that was between 1855 and 1860 when we ran ahead and stood first on all the seas, with our flag in every port. Our curve has flattened out and in 1914 we came just on a par with rising Germany.

In the second quarter of 1917 we who were watching the destruction of our merchant marine saw that with that rate of destruction of merchant marine, Great Britain could not last six months and there would be a German victory. That was the time and the reason we came into the war. Something happened after we entered it; the destruction dropped off and continued to drop at a very rapid rate until the armistice in November, 1918.

We were not building much in the third quarter of 1916, but we doubled production the next quarter and went right on up until, in the third quarter of 1917, we were building ships to equal the total destruction of ships by the hazard of war, although we had not fairly begun. Our shipbuilding speed had started, however, due to the great shipbuilding yards that were brought into existence as if by magic. A view of the Hog Island shipbuilding yard in 1918 shows 92 keels laid and many ships in various stages of completion. Last year we had an annual shipbuilding rate of more than 4,000,000 tons. We have dropped half of that now, but we have shown our speed and we did the thing that was necessary to do; we built ships.

We have grown in another way as is shown by the record of the increase of total foreign trade. The total value of exports and imports shows that we did not have very much business in 1800. We were very slow in the increase, but by 1860 the curve had begun to rise. The Civil War gave us a setback. By 1910 we found our normal rate of increase in foreign trade and in 1914 our trade was over $5,000,000,000. Then the war began and we went at once up to $9,000,000,000 of foreign trade.

Compare this trade with that of our neighbors. Great Britain was ahead from 1870 on, with a total foreign trade more than twice as large as ours, and with a very rapid increase until, just before the war began, it had risen to about $6,500,000,000. Germany had a trade of about half that of Great Britain at the beginning of this period and it was rising faster. Before 1917 she would have crossed the British curve and have been the greatest commercial nation on earth, if she had not started the war. Last year our total foreign trade went to something like $14,000,000,000, the greatest foreign trade on earth.

There are several other ways in which our interest in

[1]Professor of economic geography and cartography, University of Chicago, Chicago.

the outside world has been shown. In the period from 1870 on, it will be instructive to study the source and destination of the items making up our foreign commerce. Great Britain was first in the ranks of the buyers, rising to $600,000,000 at the time the war began. Then Great Britain bought to the extent of $2,000,000,000. Germany was our next buyer, rising very commendably until the war started. France, when the war commenced, reached $1,000,000,000 in the year. The relations we have held with these leading nations are very significant.

A study of the leading five articles of import and export in the same period shows some interesting facts. The leading article purchased throughout all this period was sugar. It ran to $100,000,000 for the whole period until the war began and then it promptly went to $200,000,000. We were buying silk, wool, hides and India rubber, raw materials of large promise which we manufacture into commodities of very high value for our own use or to sell to the outside world. Of the things we were selling in this same period, first for the entire time, is raw cotton, starting at $200,000,000 and rising to $600,000,000 in the year. Close to and sometimes ahead of it were breadstuffs with $200,000,000, then $300,000,000, and then following a crooked curve. If we have a bumper crop we can export a large demand; if we are short at home, exports are less. So the record runs, but all the time we have had $200,000,000 a year to spare, with meat and dairy products rising very rapidly. Before the war began, we had been winning an outside market in iron and steel and copper. When the war began, these foodstuffs, cotton, iron, steel and copper, went to very high figures because they are the fundamental articles out of which world war is made. Without them no nation can function in the making of world war, and we supplied in large measure the exports of the world in those lines.

We can see in another way how our position in the world has changed in 100 years. In a homolographic map of the world, interrupted to indicate ocean unities, the flow of ocean commerce is denoted by bands of color, the widths of which are proportional to the magnitude of the flow of ocean commerce. The world's greatest commercial highway is plainly shown to be across the North Atlantic between the ports of western Europe and our northeastern ports, chiefly New York City; there is no other highway on earth to compare with it. The lines across the Pacific are very slender. This calls attention to another fact, that no nation can buy very much more than it sells, and we are buying enough and selling enough to make our end of this highway. That means that the eastern part of our country is producing enough to sell to western Europe to enable us to buy back from western Europe the articles that flow over the greatest world's highway.

Growth of National Wealth

With a great continent free and untouched before them, rich beyond the dreams of men, our forefathers settled down to work. They were temperate and hard-working, they saved their earnings, invested them and worked again; and by their so doing we have grown rich. How rich, we do not know; our bankers can hardly realize it. We had such a small amount of wealth in 1800 that it scarcely shows above the zero point. It was slow in increasing, but in the 1910 to 1914 period our total wealth is computed at $250,000,000,000. That is all the wealth we have that can be computed in dollars, lands, mines, buildings, machinery, stock and everything else. In 1914 Great Britain had $90,000,000,000, and the entire British Empire $110,000,000,000, less than half of our wealth. Germany had $80,000,000,000; France, $65,000,000,000; Russia, $40,000,000,000; Japan, $28,000,000,000; Italy, $25,000,000,000; and Austria-Hungary, $25,000,000,000. We had the lion's share of the world's wealth. When the national debt is compared with the national wealth to show what fraction of the latter is cancelled or compromised by debt, the estimate for 1918 gave us only 4.8 per cent of our wealth cancelled. Our debt then was $12,000,000,000. It is now $24,000,000,000, but almost half of that is merely an investment in the hands of our Allies. They are paying interest on it and will pay it back. It is an asset, not a debt; so, if the $24,000,000,000 is put in, the real debt is only one-half that large. One-third of the total wealth of Great Britain in 1918 was cancelled by her debt. It is 55 per cent for Germany now and rising rapidly; it is 50 per cent for France. It was 66⅔ per cent for Russia, the last we heard of Russia. Japan had only 4.6 per cent; Italy has gone to over 70 per cent and Austria-Hungary's debt before it was dismembered ran to 96 per cent. If this estimate were made under the conditions of 1921, our wealth would run to $500,000,000,000 instead of $250,000,000,000; so we have grown wealthy; we have grown great.

The war came in 1914 and our position in the world was put to the test. We discovered that we could not stand aloof; that our splendid isolation was a fiction. What actually opened our eyes and made us see that in a world war it is impossible to be neutral was a recognition of the part we play in the commercial intercourse of the family of nations. That ended our neutrality long before we were willing to acknowledge the fact. Our economic advantage in the control of the major supplies of the world's most fundamental material resources, iron, copper, petroleum, corn, cotton, lumber and the like, was the critical influence. The war had not gone very far before all the belligerents saw that these supplies of ours would turn the balance wherever we placed them. It became a war for the supplies, capital, labor and credits of the neutrals; and we, as a neutral, held half the world's supplies. Of the 1,700,000,000 people in the world, our 110,000,000 as it was at the time was only 6½ per cent, but that percentage was producing almost 50 per cent of the coal and iron, 55 per cent of the copper, and just as soon as the war began 80 per cent of the world's copper, and 66⅔ per cent of the world's petroleum. These four are the fundamental things with which nations make world war and we hold the lion's share of them. We are producing 25 per cent of the silver, 20 per cent of the gold, 40 per cent of the lead, 50 per cent of the zinc, 60 per cent of the aluminum, 25 per cent of the wheat and 75 per cent of the corn. We have 41 per cent of all the hogs in the world in our own territory, and we are producing 66⅔ per cent of all the world's cotton. We have 85 per cent of the world's automobiles and, inside of our own area, there is 36 per cent of all the railroad mileage on earth. That is a record to be proud of. The question is, what shall we do with this wealth and what will it do to us? For this prize Great Britain put a blockade on the seas and for this prize Germany developed the submarine. What the blockade did to the Central Powers is very significant. It stopped one-quarter of their wheat at once. It took away from them every pound of their cotton, almost all of their wool and silk, three-fourths of their flax, all of their jute and rubber and almost all of their copper and tin. Those things are fundamental for a nation at war, and no nation

without them in large measure can conduct world war. We have a suspicion that Germany was hoarding some of these things. We know that she could not conduct the war one week after these supplies were exhausted.

Manpower

Let us see what we, as a world power, brought to the conflict, April 7, 1917. To see this clearly we must ask what the fundamental requisites are for the making of world war. They are (*a*) fighting men and many of them, (*b*) food and clothing for the line and the nation back of the line, (*c*) munitions, especially guns and ammunition, (*d*) transportation service to the front and for the nation back of the front, and (*e*) a willing support of the war by the people back of the fighting men. Each of these five fundamentals is just as essential as any other. A chain is no stronger than its weakest link. Let us run the gamut of these five fundamentals and see their significance.

In making this survey I give incontrovertible facts. It is not mere boasting to say that we are in possession of the major part of the significant mineral resources of the whole world. I will state that fact in its details for a purpose. The ownership of great wealth carries with it great obligations. Merely to boast of our great wealth and power and to use them to take advantage of our neighbors is merely to take on the role of discredited Germany, and to win, and to deserve, the hatred and contempt of all the world. But to be aware of our power and to use it wisely, will make us the greatest benefactors of all the ages.

Let us see, then, what we have in the way of great fundamentals; first, in the matter of fighting men. There was a German rule, which we knew very well before 1914, to the effect that in the populations of the West one-tenth of the total population could be counted on for the fighting units. On that basis we could have had 10,000,000 men in service, but we had 4,000,000 under arms before we had been at it two years. We had virile, educated, self-respecting men.

Let us notice how the nations taxed themselves in solving this great war problem. France had 18.7 per cent of all her men, women and children in her army. That is a large proportion. More than one-half of all the men enlisted are recorded as killed or casualties. Germany had 16 per cent plus, just one-half killed and casualties. Following down the list, Canada had 12.5 per cent of all her men, women and children serving in the army; Britain, without India, 12.1 per cent. Next come Montenegro and Roumania, Turkey, Bulgaria, Greece; and then the United States with 4 per cent. The sizes of the armies raised make a better showing for us. The largest fighting unit was raised by Russia, 12,000,000 men and *women*. Russia held a battle front of 1125 miles and by holding that front for two years made it possible for France to hold the Hun and for us to have a chance. We have forgotten that. Look at the record and see the huge loss in deaths and casualties which came to Russia. Germany had 11,000,000 under arms. France had 7,500,000. The British Empire had 6,500,000. We had 4,250,000. If we had taxed ourselves as Canada did, we would have had 15,000,000 in service or, if we had sacrificed as France did, we would have had 22,000,000 men under arms; and we would be mourning the death of 3,600,000 young men.

Food and Clothing

Food and clothing for the nation and for the army constitute the next requisite. We are better fed than any other people. The average daily ration of the average working man consists of starch, sugar, fats and proteins, four fundamental foods. The proteins are lean meat, peas and beans, or any nitrogenous foods. The food of an army is figured in calories or energy units. The average daily ration is 1140 calories of starch, 600 of sugar, 900 of fats and 360 of proteins. Then come minerals, salts and vitamines. We know that any nation or army going into the struggle must provide these four fundamental foods in proper proportion; otherwise disaster comes. Germany almost lost on account of the lack of fats; she had enough of everything else.

Looking into our cereal supply, we find that we are the largest producer of wheat on earth with an average production that is 791,000,000 bu. larger than that of Russia, which comes next. Wheat provides a good-sized fraction of our starch. Studying the record of our wheat output since 1867 year by year, we find that it is rising splendidly. Some years show a bumper crop and some years are short. In 1915 we produced 1,000,000,000 bu. All the time from 1867 to date we have had wheat to spare, but we passed the peak of our export record about 1890; at the time the war broke out we were on the downgrade. James J. Hill told us before the war began that by the year 1920 we would export no wheat, and that the day we quit exporting we would begin to import. We have had wheat enough uptodate and some to spare. In addition to wheat, we are producing three-fourths of all the corn in the world. It is a perfectly wholesome food but we eat only a small fraction of it. We feed one-third to the hogs and more than that to the cattle. Nevertheless we produce the starch.

The record from 1867 on shows the corn figures going up to over 3,000,000,000 bu. in the year. Oats come up to 1,500,000,000 bu. Then we have, of course, wheat, barley, rye and rice. When we compare our population curve with one of all cereal production, we can see at a glance that the production of cereals is barely keeping up with the increase of population. In addition to the cereals we are producing a large percentage of our starch in potatoes. Our 67,000,000 bu. of potatoes looks small when compared with the 1,600,000,000 bu. of Germany or the 1,000,000,000 bu. of Russia. Our starch supply, uptodate, has been adequate, but when we come to sugar, our record is not so good.

Louisiana produces about 250,000 tons of cane sugar. Colorado is producing just about as much beet sugar. Then we take 617,000 tons from Hawaii, 500,000 tons from Porto Rico and about 333,000 tons from the Philippines. We eat all that and call for more. Next we take almost all of Cuba's supply. We have sugar enough, provided there is peace on the seas; but if war comes we will go short on sugar and pay a fancy price again. Our appetite for sugar has grown. According to the population curve in 1880, there was one unit of sugar to each mouth; but in 1914 there were two units to each mouth. We were eating twice as much sugar and we were not producing very much. Yet, out of the importation and the production, we have had a little to spare. When Europe called on us in time of war, we had a considerable quantity to spare. We are fairly well off in sugar.

In the matter of meats we find that we are not so well off. The curves for swine, sheep and cattle running from 1867 to 1917 are flattening out, and are not at all in keeping with the rise of the population. That is one of the reasons for the high price of meat. We cannot count on sheep very much for food; we are raising most of our

sheep for wool. When we come to hogs, we have 67,000,000 animals. Compare that with Germany and Russia and the rest of the world. Our supremacy is plain. Remember that the hog is the best machine for transforming cheap and common food into high-class human food. The hog, by eating the common food, gives us ham and bacon, that is protein, largely. The hog gives us fat, and fat is the most important thing. Out of our hog supply alone, we can almost furnish our fat supply; so, by supplying proteins and fats the hog is a splendid resource. It is an annual crop also. On the map it is plain to see that there is a hog belt which coincides exactly with the corn belt, for obvious reasons.

A study of the oil supply could not have been made until after the war began. It took the threat of a shortage of oils to arrest the attention of the world and get the data together. Our Government assembled the data. We were producing 1,300,700,000 lb. of butter and eating it all. Then we had tallow and packers' grease and oleo stock and garbage. A surprising thing is that we are producing at the same time almost exactly as much cottonseed oil as butter and the former goes mostly into the food as a substitute for butter and lard. Cottonseed oil is a wholesome, perfectly agreeable human food and we have it in large measure. The linseed oil is not a food. Cocoanut oil is a food and the hope of the world is largely in the cocoanut. Out of our total oil supply, we can spare for other nations 1,000,000,000 lb. each year. We are safe on the oil supply uptodate.

We are well favored in the matter of clothes. When we remember that the great majority of the people are clothed in cotton most of the time, we appreciate what an advantage we have. Smokeless powder calls for cotton. Without cotton there could be no war. If the other countries want war, they must buy our cotton. We have it to sell or to withhold from selling. The cotton is produced in a small area in the southeastern part of the Country. If our agriculture were as intensive as that of the Japanese and Chinese, we could produce all the world's cotton in that area for an endless time to come. But we are losing ground in the matter of cotton supremacy.

When it comes to wool we are not so well favored. We have two areas of concentration of sheep. One in the East Central States is largely for meat, but also for wool; the one in the West is largely for wool. When we see all those sheep we think we have wool enough, but we have not. We were producing in 1914 only 256,000,000 lb. of wool and importing 325,000,000 lb. for our own use. We have no wool to spare. Great Britain produces less than one-sixth of the wool she uses; France is worse off and Germany still worse off. We cannot go without tomorrow's bread but we can go without wool for a long time.

The increase in textile manufactures from 1850 on makes a splendid showing, coming up to more than $1,000,000,000 worth of cotton manufactures, $500,000,000 of wool and $250,000,000 of silk. We produce no silk. We are the largest buyers, the largest manufacturers and almost the largest users of silk on earth. This is merely evidence of what we are doing with our opportunities and what place in the world we are going to hold soon. The clothing item is most important in time of war. An essential part of it is leather. Nearly one-half of our leather supply goes into the making of shoes and boots. The total value of our leather manufactures is $1,000,000,000. We have begun to export boots and shoes tremendously. A good sized fraction of the boots and shoes worn outside the United States comes from our Country.

Munitions Materials

We have little to say for ourselves regarding munitions but we possess the fundamentals out of which they are made. Coal is the most significant fundamental resource of this or any country, so far as industry and commerce are concerned. Of all the known coal in the world, of which there are 7⅓ trillion tons that can be mined under present circumstances, we have over one-half, or 4 trillion tons in our own area. The next largest owner of coal is Canada, with 1¼ trillion tons. China comes next with a trillion tons. Far below China, for China has more than all Europe, comes Germany with a pitiful 0.4 trillion tons, and then comes Great Britain with less than half of that. Before the war began we had an output of 575,000,000 tons; Britain 322,000,000 tons; and Germany 282,000,000 tons. It is evident how small the rest of the world is in the matter of coal consumption and production. There are just four nations on earth that can make or prevent world war. They are the United States of America, Great Britain, Germany and China. Two of them can in fact make world war, and our Nation is one of them. Our record from 1850 on in the great fundamental of coal production is very significant. The production curve starts close to zero in 1850 and grows to an output of 650,000,000 tons for one year. Great Britain at the same time is falling behind. Germany was increasing faster than England and promising to parallel the British output; but she was still far behind us. It is the same with iron. We started at about zero in 1850 and have risen to 39,000,000 tons. The best Germany did was somewhat less than 20,000,000 tons; Great Britain produced slightly less than 10,000,000 tons; and France mined about one-half of that amount. We have the coal and the iron. We have also the lion's share in larger measure of copper. Copper goes into the making of shells and into the making of wires for electrical machinery. Without it there can be no world war. If other nations want copper they must come to us. We are producing 80 per cent of the world's copper.

We have the major share of the world's petroleum also, as an energy asset. It seems that all we need to do in Texas is to bore a hole in the sand and oil sprouts up ready to be piped, refined into gasoline and sold the world over. So we have the chance to supply the world with its liquid fuel in large measure. The next largest producer is the Baku region in Russia and then comes Mexico. The production of the rest of the world is very small. We have produced about two-thirds of the world's output from the beginning in 1875, and which has risen rapidly to 500,000,000 bbl. per year. The curve of Mexico has crossed the 100,000,000-bbl. mark and is going on up. Do not forget that this was a war of motor vehicles. Without gasoline we could have no motor trucks, flying machines or submarines.

In the matter of munitions we began to manufacture small arms for the Allies as soon as the war began, and we were at it for two years. We commenced at once to make big guns; the only big guns we had that got into service came from the battleships. The longest range of the ordinary gun when the war began was 15 miles. We made a gun that has a range of 39 miles. It reached France but did not get into service. However, we did have men and money and food and raw materials, the things which our Allies in Europe wanted so sorely. We

(*Concluded on page* 150)

Cushioning in Motor-Truck Design

By CHARLES O. GUERNSEY[1]

MID-WEST SECTION PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

MODERN high-quality motor trucks are being designed with the idea of rendering the maximum of satisfactory service in the hands of the user. The more progressive motor-truck builders realize that a permanent business can be built only upon quality as a foundation. The maintenance cost is so much more than the first cost, even with a first-class vehicle, that quality must be paramount. A high-quality 2½-ton truck, for instance, will cost between $25,000 and $40,000 for operation over a life of 100,000 miles, depending upon the design of the vehicle and the service for which it is being used. Obviously, it is poor economy for the user to purchase a truck which will cost an excessive amount for upkeep after a few months of service and which never can render more than perhaps 30,000 miles of service. Truck users are awakening to the fact that a few hundred dollars added to the initial cost of a vehicle may save thousands in the cost of operation.

As a result of these conditions the majority of the reputable truck builders are at this time attempting to supply a high-quality product, which will operate over a period of years with the minimum of maintenance expense. To this end, provision is made for easy adjustment or cheap replacement of worn parts throughout the chassis. This is shown by the use of adjustable bearings in the engine, the wheels and the transmission, and at the differential; and by the use of inexpensive removable bushings at the points of less wear, such as brake-shafts, spring-eyes and steering connections. It is obvious that much thought has been given to this phase of the maintenance problem. However, many designers lose sight of the effect of shocks and strains, which is of even greater importance. A truck is scrapped for some one or a combination of the following reasons:

(1) Obsolescence of design
(2) Wear on vital parts which cannot be replaced economically
(3) Failure of parts, due to shock loads, fatigue or crystallization

In these days of changing fuel conditions and rapid development along all lines, obsolescence of design is of some importance. However, it certainly is not responsible for more than 10 per cent of the casualties among old trucks. As previously outlined, all high-class builders are safeguarding against wear on vital parts to a greater or lesser degree. The failures from this cause are, of course, largely in the hands of the operator, since proper lubrication, adjustment and inspection are essential in reducing them to a minimum. However, the important factors in truck life which are being overlooked are covered under failure of parts. Metal parts of all kinds undergo a change in structure when in severe use, resulting sooner or later in the failure of vital parts such as crankshafts and connecting-rods; clutch, propeller, transmission and axle drive-shafts; and frame members. In addition, there is a great amount of excess wear in bearings and other vital parts throughout the chassis, due to shock loads. The percentage of failures and wear in all of these parts can be reduced very materially by properly cushioning the truck to eliminate the brunt of shocks and strains arising in its use.

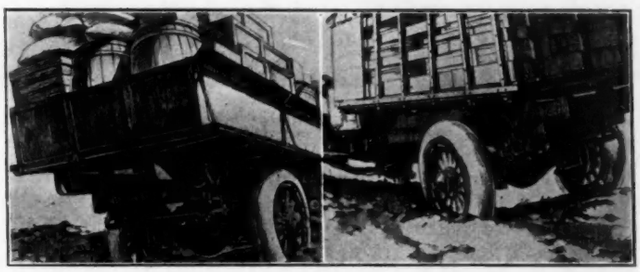


FIG. 1—THE STRESSES DUE TO THE LOAD (AT THE LEFT) AND THE TWISTING STRAINS DUE TO IRREGULARITIES IN THE ROAD (AT THE RIGHT)

CHASSIS STRESSES

The stresses and strains set up in a motor-truck chassis can all be classified under one or more of the following headings:

(1) Stresses due to the load
(2) Twisting strains due to road inequalities
(3) Shocks caused by rough roads
(4) Driving shocks and loads
(5) Braking shocks and loads

All the load-carrying parts such as the frame, springs, body, axles and tires, are affected by load stresses. While there are some shock loads arising from this source, due to pitching from side to side, in general the stresses are more or less of a static nature, as indicated at the left in Fig. 1. The stresses covered under the heading of road inequalities are of a twisting nature, caused by diagonally opposite wheels dropping into low places in the road. With the conventional construction, this unevenness of roadway causes weaving or racking of the frame. The springs usually supplied cannot take up all these inequalities. The limit of action for a conventional front spring is about 3 in. and about 5 in. is the limit for the rear spring. The result is that if the frame were perfectly rigid with a conventional suspension, diagonally opposite wheels cannot pass over obstructions more than 4 in. high without tending to lift the other wheels off of the ground. Terrific strains would be set up under these conditions, even if it were possible to make a frame sufficiently stiff for the purpose. Manufacturers generally make the frames flexible, as shown

[1]M.S.A.E.—Chief engineer, Service Motor Truck Co., Wabash, Ind.

FIG. 2—A SPECIAL SPRING SUSPENSION DESIGNED TO ELIMINATE TWISTING OF THE CHASSIS

at the right in Fig. 1, to permit the road wheels to conform to these road inequalities. In fact, it is practically impossible to make a frame which will be rigid under these conditions. This flexibility, however, has serious drawbacks in causing twisting and weaving in the body, cab and hood, and in throwing parts out of line. This twisting also makes it necessary to use elaborate three-point suspensions on engines and transmissions. If a spring suspension is used which eliminates this twisting tendency, much can be gained. The frame can then very easily be made sufficiently rigid to prevent distortion of bodies, seats and hoods, and misalignment of units.

We have used with very gratifying results a spring construction which puts the entire truck on a three-point suspension. This special spring suspension was developed with the idea of obviating the twisting strains. We used the conventional semi-elliptic springs in the rear with a cross-spring in front, trunnioned up the center, as is shown in Fig. 2. That does away entirely with the twisting of the frame and compensates for the road shocks, strains and twists, in a fairly satisfactory manner. With the left front wheel high and the right front wheel low, as shown, the position of the wheel with respect to the fender and the extreme deformation can be seen, yet the frame is perfectly straight. This illustrates the possibility of designing springs to eliminate the different strains. With a lift of 6 in. on one front wheel and neglecting spring action entirely, the lift on the frame is only 3 in. In addition to this advantage, all distortion of the frame is eliminated by the perfect flexibility of the spring arrangement. A truck so constructed can be driven loaded over cobblestone pavements with remarkably little vibration above the springs.

Fig. 3 is a view of an English chassis, the Palladium, showing a special spring suspension to give better riding qualities than are secured with the ordinary spring suspension. Much can be done along that line. Taking a 1½-ton pneumatic-tired truck as an illustration, the rear-end weight above the springs is about six times the rear-end weight beneath the springs when the truck is loaded. In ordinary passenger-car practice the unsprung weight is about one-fourth of the sprung weight. This indicates that it should be possible to make a 1½-ton truck ride better than a passenger car rides when loaded. When unloaded the ratio is about 3 to 1 as against 4 to 1 in the case of the passenger car; so, even there we should be able to make trucks ride more easily. When we make trucks ride better, the wear-and-tear on the chassis, the load, the road and the driver is reduced.

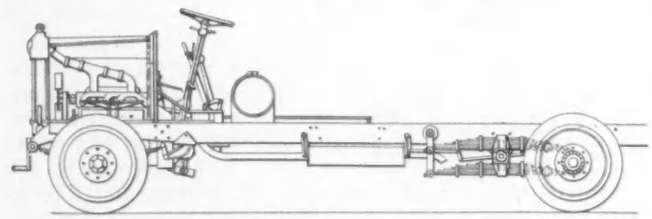


FIG. 3—AN ENGLISH CHASSIS EQUIPPED WITH DOUBLE CANTILEVER SPRINGS

PNEUMATIC-TIRE CUSHIONING

According to our division, rough roads undoubtedly do more damage than any other type of shock. This includes the terrific vibration due to cobblestone pavements and the short, rapid impacts due to sharp holes and bumps in the road, indicated in Fig. 4. These shocks cause vibration throughout the truck which results in the loosening of various bolts and connections, the cracking of soldered joints, the breaking of copper tubing and the crystallization of all sorts of parts. This type of shock if not properly absorbed will cause fatigue sooner or later, regardless of the quality of the steel or the heat-treatment used in its manufacture. These shocks can be reduced largely by careful design of the springs and the use of live or resilient frame-members of wood or pressed steel as opposed to the heavy inert rolled-steel

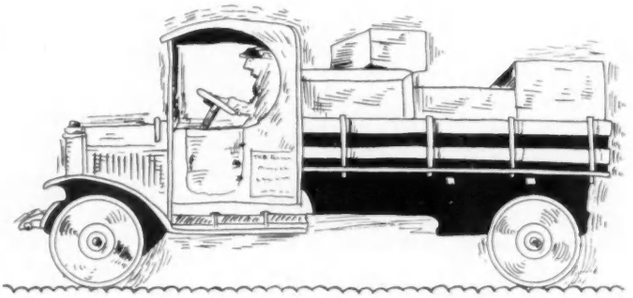


FIG. 4—THE TYPE OF SHOCKS CAUSED BY COBBLESTONES AND CAR TRACKS

type. Naturally, the tires are the most important factor of all. If conditions are such that pneumatic tires can be used satisfactorily, they will in a large measure furnish a solution of the difficulty. Oftentimes, imperfect or badly worn solid tires are used and about the only real good they do is to deaden the noise. The impact forces vary according to load, speed, spring suspension and the like, but the following statements are true approximately.

It has been shown that a pneumatic tire loaded to rated capacity deflects 11 times as much over an ordinary obstruction as a solid tire which has 1 in. of live rubber; and five times as much as a new solid tire, shown in Fig. 5. These tests were made by putting a load on the spindles of wheels having these respective tires and then measuring the deflection. Under a 7000-lb. load the 36 x 6-in. solid tire deflected 0.7 in., while the 40 x 8-in. pneumatic tire deflected 3.4 in. That gives us a reasonable measure of the relative stresses, other things being equal. The impact force is inversely proportional to the deflection. Even with new solid tires the impact forces are three times as great as with pneumatic tires. This means that a pneumatic-tired truck running at 24 m.p.h. will not set up any greater stresses than a truck with new

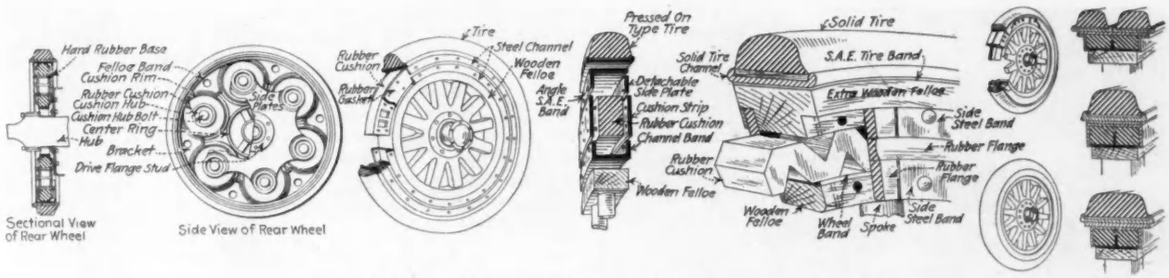


FIG. 6—VARIOUS TYPES OF CUSHION WHEEL IN COMMON USE

solid tires running at 8 m.p.h. The impact forces with pneumatic tires rarely exceed the static loads by more than 50 per cent. With solid tires the impact forces may in extreme cases run to 1000 per cent of the normal load. Pneumatic tires, if they prove satisfactory from other standpoints, will contribute largely to the reduction of stresses due to road impact. We must remember also that excessive wear-and-tear on the highways will cause opposition to the use of trucks. We must design trucks so that they will cause the least possible damage to the roads over which they travel. The truck which can accommodate itself best to the road will, in turn, cause the least injury to the road. The wear-and-tear on roadway surfaces is largely a matter of impact.

Fig. 5 shows, at the left, a 44 x 10-in. pneumatic tire dropping off of a 2-in. bump and striking with an impact force of only 8000 lb. with a live load of 7000 lb.; at the right is shown the corresponding size of dual solid tire dropping the same distance at the same speed, but having an impact force of 45,000 lb. The impact in this case is more than six times the amount of the live load. That impact affects the wheel bearings, the spindles and all of the unsprung parts just as if they had been hit by a hammer-blow of that amount of force. The pneumatic-tire impact was very little over the rated load. So we must remember that the truck which can conform to road inequalities and absorb shock will at the same time inflict less damage on the road.

These statements may lead to the belief that I am an advocate of pneumatic tires. This is not necessarily the case. While the advantages resulting from their use are of great importance, we must realize that there are disadvantages which must be considered fully. For some applications they are proving ideal; on others they are not suitable. On the large heavy-duty trucks, for instance, they are at this time practically out of the question. It is these trucks which suffer most from impact and in turn inflict the greatest damage on the roadway.

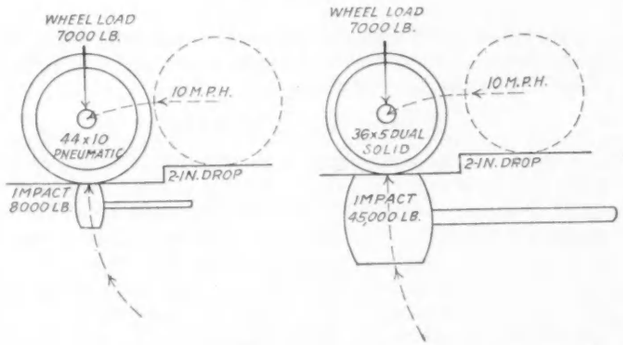


FIG. 5—A COMPARISON OF THE IMPACTS PRODUCED BY PNEUMATIC AND SOLID TIRES FALLING THROUGH THE SAME HEIGHT

For the present, we are forced to look elsewhere for a means of cushioning heavy trucks against rod shocks.

CUSHION TIRES AND WHEELS

As a result of efforts along this line, we have several types of cushion tire which hold considerable promise. The cushion wheel has proved its worth, although many of these wheels add so much to the unsprung weight that the advantages are offset to a great extent. Fig. 6 shows types of cushion wheel. To illustrate some of the possibilities of cushion wheels and of increased cushioning of any kind, in the case of an electric chassis which was originally equipped with solid tires and standard wood wheels, it was possible to get a speed of 9 m.p.h. in ordinary service. Another vehicle, an exact duplicate, equipped with caterpillar tires and the cushion wheels, was attaining 14 m.p.h. over the same route under the same conditions. After trying a number of different expedients, the users switched the cushion wheels and tires and obtained the 14 m.p.h. on the other vehicle; the increased cushioning had decreased the rolling resistance so that the electric motor was able to propel the vehicle at a higher speed.

Much wear-and-tear can be saved on trucks equipped with solid tires by promptly discarding a solid tire which has worn down to within 1 in. of the hard-rubber base. A recent inquiry among a number of large users, such as the Standard Oil Co., American Railway Express Co., Wanamaker's, Marshall Field & Co. and The Fair Store, showed that this is general practice with fleet owners. The use of a badly worn or defective tire can do damage to the truck in a few miles of running amounting to the price of a new tire. The tire companies can be of great service to the industry by adjusting solid tires on the basis of 1 in. of rubber in a worn-out tire. As it is, many of them insist that a tire is not subject to an adjustment as long as there is any sign of live rubber on the base.

The realization of the advantages and shortcomings of pneumatic tires is leading to a considerable demand for a tire which will to some extent at least combine the advantages of solid and pneumatic tires. The result is a considerable interest in various types. These tires combine to a lesser degree the cushioning, speed, and traction possibilities of the giant pneumatic tire with the low cost and dependability of solid tires. Fig. 7 shows various types of cushion tire. The use of resilient frame-members, improvement in spring suspension and in tires and better design in other ways, will greatly reduce the damage resulting from road vibrations. Certainly this phase of the problem merits our best consideration.

The solution of the problem lies not so much in the elimination of shock as in reducing its intensity, by distributing the force of impact over a greater length of time. If a man jumps out of a fourth story window to

FIG. 7—DIFFERENT CUSHION TIRES FOR USE ON TRUCKS

the pavement, he is killed or seriously injured; but if he jumps into a life net he is not harmed. The force is the same in both cases, but the impact is distributed over a greater length of time when the man lands in the net. Means must be employed to distribute the force of impact in a truck over a greater time in a similar manner, thus reducing its intensity.

Fig. 8 portrays the driving shocks. A tremendous load is put upon the parts when the engine is applying its power through the transmission, the rear axle and the different gears and shafts along the line. When running along under ordinary conditions the strains are not so severe, but when the wheel spins and then suddenly takes hold, it causes a tremendous shock all through the parts. If the brunt of the shock can be eliminated in some way, for instance, when the clutch is suddenly dropped in or in a case where the wheel is spinning and then suddenly takes hold, the stresses in these parts can probably be cut down at least 50 per cent. There are a number of ways of doing this and on many different trucks various methods are employed along that line; for instance, the Hotchkiss drive, in permitting a certain displacement of the axle, helps to a great extent in dissipating or cutting down the amount of those shock loads. This is illustrated in Fig. 9. Whether these blows have the effect of a hard steel hammer or of a soft rubber hammer depends upon the absence or provision of cushioning factors. Parts in a properly designed vehicle are not broken by the steady torque or weight load. It is the exceptional shock load which causes stresses beyond a safe limit and finally causes failure. Still another type of shock, the braking load, is simply the reverse of driving or torque shocks, as indicated in Fig. 10. Various parts are affected

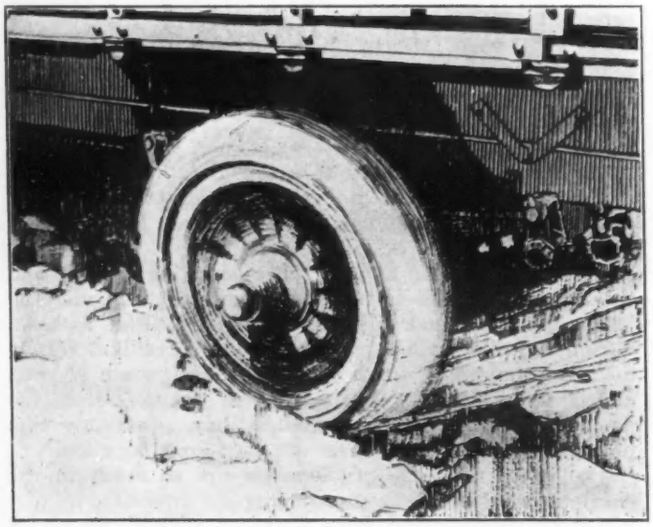


FIG. 8—DRIVING SHOCKS EXPERIENCED BY A TRUCK

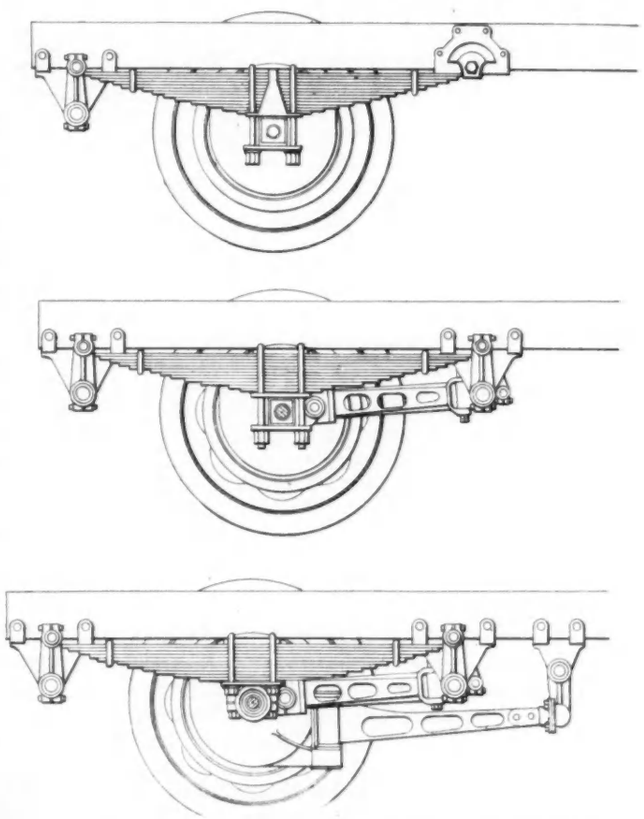


FIG. 9—CONSTRUCTIONS DEVELOPED TO REDUCE THE SHOCK LOAD TO WHICH A TRUCK IS SUBJECTED

according to the design of the brakes and depending also upon the engagement or disengagement of the clutch when the brakes are applied.

ELIMINATION OF VIBRATION

Vibration, caused by shocks of the varied kinds, is the most destructive factor which must be overcome in motor-truck design. The designer who succeeds in reducing shock or vibration stresses can make a lighter vehicle and also a more satisfactory product than possibly can result from heavy inflexible design, assuming of course an equal standard of engineering in other respects. A sportsman would never think of using a fly-casting rod which was as stiff as a broom handle. He would be certain to break his line. Instead, he uses a light pliant

rod which smooths out the load on the line so that there is no danger of breakage. There are already many features of design which help to some extent in achieving this point. Great improvements should be expected in spring suspension. We have made brief mention of one special spring suspension which has shown good results. We should not overlook the possibilities of a suspension having a graduated deflection. This can be achieved by using light springs, together with auxiliaries of some sort which come into action under extreme deflections or loads. We have been too prone to accept the conventional in this regard. A line of practical investigation along this line, conducted by a practical engineering staff, should show some remarkable results. Another feature which is of considerable value is the use of pressed steel or other shock-absorbing material for frames.

The circumferential displacement of the tires, of course, helps to some extent. The use of flexible-fabric universal-joints is of material help in that connection. Graflex pictures showing flexible-fabric universal-joints in service, taken when operating on low gear, show that they do deflect a very appreciable amount under certain conditions, and thus smooth out the torque curve between the engine and the rear axle. In this way wear and breakage are reduced in all torque-transmitting parts. These joints do for the driving line what the cushion does for the driver. Several years ago a chain-driven truck kept breaking jackshaft bevel pinions continually. An investigation showed that this breakage resulted from shock caused by a fierce clutch and by the slack in the driving chains. The use of a fabric universal-joint cured the trouble.

Engine vibration can be reduced materially by proper mounting. The engine should be anchored in such a way that it cannot possibly vibrate in its mounting. It is perfectly possible to mount an engine so that slack, with consequent vibration, cannot develop during the life of the truck. For instance, the use of a stiff spring on the engine-support bolts and on the trunnion bearing cap at the front point of suspension in the case of a three-point mounting, will hold the engine tightly in place and still permit the usual weaving and twisting as required with a conventional spring suspension.

A truck when properly cushioned will have less wear-and-tear and less shock breakage and carry its load with the minimum of damage. As a result of shock reduction the chassis can be made lighter. This, in turn, will reduce the amount of power required, thus further decreasing stresses. This will lessen tire wear, gasoline consumption and other items of operating and maintenance expense. Another possibility lies in increased speed. I predict that as a result of the use of scientific cushioning in design we will see trucks within a short time which are at once lighter, stronger, more economical because of lighter weight, faster and, in general, more suitable for use than present designs. The truck must conform to the road. It cannot be built so as to resist punishment from the road. It must be capable of receiving, absorbing and nullifying road shocks. It must be properly cushioned.

THE DISCUSSION

B. S. PFEIFFER:—Did Mr. Guernsey use any radius-rods on the front axle with the cross spring?

CHARLES O. GUERNSEY:—We have to do that. We have a three-cornered radius-rod since that is the only thing that can be done successfully.

F. E. BLANCHARD:—One thing that has been causing much damage to motor trucks recently is the lower gear-

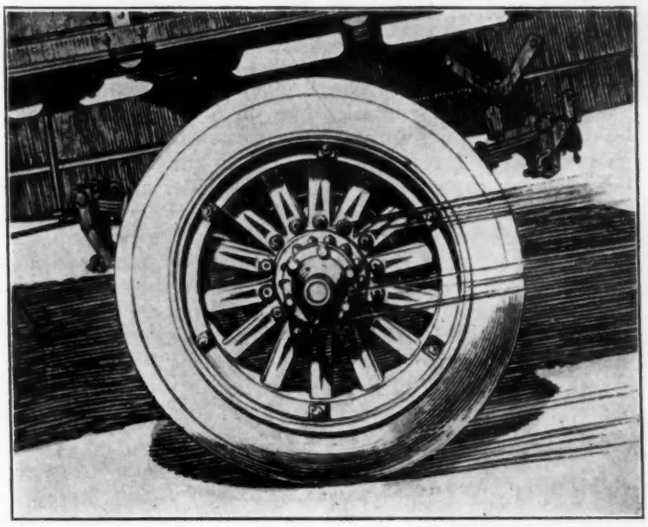


FIG. 10—STRESSES SET UP IN A TRUCK WHEN THE BRAKES ARE APPLIED

ratios used and the higher tractive effort. I have been in a district lately where much damage was being done to all types of truck. It was not done at speed, but under low-gear conditions where truck towing was done with and without tow-hooks. One truck may be down in a hole and another truck pulls the first one out. Instead of properly equalizing the towing chain, the driver generally wraps one end of the chain around one of the side-rails of the truck frame, puts his truck in low gear and proceeds to pull the other truck out of the hole. I have seen in one case a 3½-ton truck pulling two 100,000-lb. freight cars, with a chain wrapped around the left side rail of the truck. I had no means of measuring the deformation of the truck frame, but it went out of square between 1 and 2 in. The driver was rather proud of the effort, instead of realizing what he was doing to the truck frame. To show such things by motion pictures would benefit the trade in general. In similar cases I noticed engine supports and rivets torn loose, transmissions that it was impossible to keep tight, gusset plates torn in two, cross-members broken and many rear-frame cross-members pulled out. There is a great amount of such abuse that should be corrected.

MILTON BECK:—Much good has come to a number of new industries by collective advertising. The cement business was at a very low ebb a few years ago. Then the cement people issued advertising along the lines of what can be done with cement and how to use cement. Perhaps some company's name appeared, but the advertising was largely a building up of the cement business. If the men who do the advertising in the motor-truck business could devise some collective advertising scheme whereby these troubles could be emphasized, it would help the truck business very materially. The truck business really deserves a campaign of education on the use of trucks and how to use them to get the most service.

L. W. PIETSCH:—Knowing that their trucks will be used at some time as a motive power for towing, I believe it behooves the builder to improve the construction of the truck-frame bracing. This would help to eliminate much of the twisting strain which distorts the body and would tend also to eliminate the shocks from the truck wheels to the engine.

MR. GUERNSEY:—We are all hoping that the pneumatic

tire will succeed, because it makes our work much easier, but we are obliged to go according to the evidence. Probably it will win out eventually on 1, 1½ and 2-ton trucks, and possibly on larger ones. There have been some experiments with pneumatic tires on 5 and 6-ton trucks; some of them have proved very successful in an experimental way. I refer particularly to the Goodyear six-wheel truck experiment. The truck rides and performs well on the road. It is possible to use the same size of tire on each wheel, and the same pressure on each. A tetering movement obtained in going over bumps seems to absorb the shocks. I rode on one of these trucks over so rough a brick pavement that an automobile that was going alongside at probably 10 m.p.h. was bounding up and down. We drove down that street at 30 m.p.h. with a 6-ton load. Four of us were sitting in the back of that six-wheel truck; we had no cushion and were perfectly comfortable. That indicates the possibilities of pneumatic tires if they can be made to stand up well enough to keep the repair cost within a reasonable figure.

Until we can get a spring suspension that will take up the road twists and the inequalities, we practically are obliged to use the flexible frame. An ordinary front spring will deflect about 3 in. and an ordinary rear spring will deflect not over 5 in. We have, as I mentioned, built a truck with semi-elliptic springs in the rear and a single cross-spring in front with a trunnion in the center, and we are going to market it that way. It seems to work out very well. We put the engine on a four-point mounting and, for testing purposes, put on a load that was pretty high from the ground. The front end rode well, but when the rear wheels hit a bump it would swing off sidewise. We were able to get around that by making the rear springs long and putting in rebound leaves. The effect we get now is that if one front wheel of the truck goes down in a hole it is scarcely noticeable. Then, when the rear wheel comes along and hits that hole, it just drops off a little bit sidewise. So, we have been able to get a remarkably easily riding truck. The platform spring in the rear is all right, but usually lateral stability is needed in the rear more than in the front, because the rear springs are the stiffer and carry most of the load. If we put a platform spring in the rear and then attempt to maintain the lateral stability from the front springs, we sometimes get into trouble.

Referring again to the Goodyear six-wheel truck, the Department of Agriculture made a test of that truck and found that each of the four rear wheels had about the same impact effect as the rear wheel of a pneumatic-tired 2-ton worm-drive truck with its rated load. In other words, by dividing up the load among four smaller wheels and using smaller tires, not only were better riding qualities secured and the damage to the truck reduced, but the impact force exerted on the road was actually cut to about one-seventh what it would otherwise have been. So, it may be that we can install multiple axles under the rear end of the big 5-ton trucks and divide the load so as to reduce the terrific impact force.

If there is a cushioning factor in any part of the chassis, whether it be in the load-carrying or in the driving parts, which will cut down the shocks and stresses in those parts one-half, the size of those parts could be reduced to a great extent. If we can save weight in the chassis, we can save cost for the operator. By incorporating cushioning features we should be able to make an appreciable reduction in the chassis weight. According to figures showing the operating costs for different sizes, from 1½ to 5-ton trucks, it costs between 4.5 and 10.0 cents per ton of gross weight of load, chassis and body, to move a truck over the road. If we can reduce the weight 1000 lb., we will say, on a 5-ton truck, we can save about 3 cents per mile for the operator.

R. M. GASTON:—In connection with the spring coupling, I know of one particular design of railroad motor-car which was designed with a spring coupling between the engine and transmission. In this position it transmitted only the engine torque and was very successful. It is commended particularly for railroad car use because the cars have no rubber tires and there is a very limited flexibility in the drive. A number of them were built and seemed to be successful. It might not be out of reason to use something of that kind on a truck, especially where solid tires are employed.

MR. GUERNSEY:—The flexible rubber and fabric universal-joint serves much the same purpose. A spring coupling probably would give a greater angular displacement under a certain shock, but the flexible rubber universal-joint minimizes the blow. A spring wheel will not stand up on the road, because it cannot yield to the instantaneous blows. There is too much inertia. We might encounter similar difficulties with a spring coupler, but the rubber will yield to instantaneous blows because, practically, there is no inertia. Rubber might serve the purpose better even than a spring shock-absorber. We tried one of the latter between the propeller-joint and the flange. It weighed about 40 lb. and worked well, but we concluded that it introduced an unnecessary weight.

MR. BLANCHARD:—Are the impact forces you have given taken from actual tests, or are they from empirical data?

MR. GUERNSEY:—They are taken from actual tests.

UNIVERSAL-JOINTS

A MEMBER:—I am informed of a serious trouble with the fabroid joint. Several of the major companies in the East have made extensive tests on it and with the three-point joint, in which two planes travel but not in the same line. The results have shown that a hammer-blow occurs when the shaft is inclined at an angle of 4 deg. or more, which is repeated three times in every revolution. That effect has been very detrimental to several makes of car. One of these companies that produces a light car has had to change the construction in both the transmission and the rear axle due to that trouble. This company will attempt to remedy the difficulty in several different ways, one of which is to reduce the shaft angle, which has been proved to be less than 4 deg., and otherwise to strengthen the construction. One company is installing the fabroid joint between the engine and the transmission, using an entirely separate joint to relieve the engine from the stress shocks and allowing them to come up through the axle, the transmission and the propeller-shaft, and the method has met with success. I believe we are to see a mechanical joint on one of the new cars this year. This difficulty has been found to be a very serious thing to contend with. I do not know whether Mr. Guernsey has had any experience with those high shaft-angles, or whether his experience would corroborate mine. One of the larger companies is working with a joint now which is a true universal-joint. The joint that we have now is more of a flexible coupling. The company to which I refer is working with a prong joint having a thicker disc and has obtained results that so far are very satisfactory. I have taken this question up with some of the engineers of several of the companies that manufacture these joints. They have admitted the

condition, recognize it to be a serious one and have attempted to correct it in several ways. I know of three large companies at present that are considering changing the joint, or the construction or whatever is necessary to get rid of that condition.

MR. GUERNSEY:—When we first began experimenting with the flexible fabric joint we tried it both ahead of and at the rear of the transmission. In our particular line the transmission is about amidships. In the case of some short-wheelbase trucks where this joint was used back of the transmission, we had some difficulty because the angle was too great; but it has been our experience that where the maximum angle obtained under the worst condition does not exceed about 4 deg., the end-thrust or the hammer-blow in an endwise direction is serious enough to cause concern. In fact, the blow, being administered through rubber, is deadened. If there is an extreme angle, it causes a bad condition. It has been our practise to employ the flexible fabric construction between the transmission and the clutch, using the standard metal joint back of the transmission. The shocks are absorbed at some point in the line, so that it makes little difference where it is. If provision is made somewhere in the line to take care of this condition, the case will have been covered. It is not necessary to use flexible fabric joints all through. In the case of a unit powerplant design, we are using a flexible fabric joint on the axle end of the propeller-shaft and a metal joint on the transmission end. An advantage of this arrangement is that, as the axle is displaced in riding the road, an excessive end-thrust is not being put on the bearings; that is accommodated through the slip joint. Where two flexible fabric joints are used between the transmission and axle without the slip joint, as is done by some companies, this is not the case.

A MEMBER:—In experimenting with the flexible joint behind the transmission, do you have any trouble with the bearings in the transmission?

MR. GUERNSEY:—No; we equipped about 50 trucks, built about March, 1915, and I daresay 40 of them are still running with the original shafts.

MR. BLANCHARD:—Was that a straight-line drive?

MR. GUERNSEY:—It was supposed to be straight-line under load, but some of the rear shafts on dump trucks were very short. We did get some extreme angles on them in rebound and with extreme load, and we had trouble with the bolts that carried the discs. They broke off because of the constant bending back and forth.

CONCRETE ROADS

B. B. AYERS:—The concrete road will rule ultimately. There is as yet no material except concrete that will stand up. The construction companies should advocate universal adoption of the concrete road. Without doubt this will be accomplished, and we will begin to see results within about five years.

MR. GUERNSEY:—I am doubtful about that. I have seen some concrete roads that were considered very fine on which the surface was broken down due to the abrasion of passing vehicles. I am inclined to think that we need to put in a good road foundation and then put an asphalt coating on the top to take care of the abrasion. Cushioning in the road is just as logical as cushioning in the vehicle.

MR. AYERS:—Such abrasions are due to poor mixtures. In Wayne County, at Detroit, in five years there has been no abrasion whatever, because the roads were laid with a mixture that was absolutely perfect and carefully supervised. In that time the concrete and gravel wore down evenly and left no holes, because the mixture was homogeneous. Our great trouble will be in obtaining good engineers who will make the proper selection of materials and lay them right.

CHAIRMAN G. I. BRIGGS:—What information have you on California concrete roads?

MR. AYERS:—California has climatic conditions that do not apply in the East. Eastern roads are sometimes subjected to temperatures of from 8 to 40 deg. below zero Fahr. in winter. The fine new concrete roads in Wisconsin are subject to these low temperatures. They must withstand leakage and seepage, freezing and thawing. I think it is marvelous that those roads can be maintained at all under such circumstances. There is not a single devastating element of that nature to contend with in California.

MR. BLANCHARD:—Mention has been made of the road between Detroit and Toledo and how it disintegrated. This road was too narrow in the first place. At the time it was constructed there was a great demand for inter-city transportation. Many Army trucks were being built at Detroit. They traveled from Detroit to Toledo and brought goods back. The Army truck drivers needed plenty of clearance. The result was that they ran over the concrete edge of the road and started breaking down the edge. As soon as that occurred and frost entered the roadbed, the bad spot immediately began to progress toward the center of the road. In some cases there are oval bad spots that have gone in almost to the center of the road. This also has been the cause of many accidents.

A MEMBER:—The conditions under which that road was built were probably as bad as any we have had to contend with. They have bottom conditions there that have been almost impossible for the last 20 years. They should have taken twice the amount of money they did to build that road, and they will be forced to do so eventually. The bids on some roads in Illinois range from $42,000 to $45,000 per mile. Bridges must be constructed that are practically as good as those built for a railroad, or they will not stand up under the heavy trucking service. This will cause contention between the users of passenger cars and the users of trucks.

A MEMBER:—I made several trips last winter and in the early spring over the road between Toledo and Detroit, and know some of its history. One of the construction superintendents told me that it had about a 10-in. base, 8 ft. wide, and that the sides fell off to 6 in. in depth. We made the trip at night several times. At that time they were doing a considerable trucking of engines from Detroit to Toledo using heavy trailers, and there was considerable sway at all times on them. I have wondered whether the truck builders took into consideration the sway and pitch on the trailers. The load on the trailer was as heavy as that on the truck itself. The truck builder should work with the highway engineers and the road builders in that connection.

MR. GUERNSEY:—An attempt is being made along that line at present. The Federal Highway Council is made up of men prominent in the automobile and motor-truck business and leading highway engineers. They have an appropriation for the study of sub-grades, foundations and road surfaces. The idea is to try to arrive at some specification for the proper road to meet certain conditions in the various localities. They consider the drainage of the sub-grade and the matter of seepage, which was mentioned as being the paramount thing. They

assume that there must be a sufficiently heavy foundation and that the proper surface must be determined, but the thing that seems to be making them the most trouble is the question of draining the sub-base.

Liquid Loads

MR. PIETSCH:—Have any experiments been made as to the difference between liquid loads and dead-weight loads carried in trucks and what relative difference there is? My experience with liquid loads indicates for instance, that a 2-ton truck should really be rated as a 2½-ton truck. We have trucks in the service of carrying liquids. Those liquids are swish-swashing around all the time and, in going around corners, the strains are in different angles all at the same time. I believe that at least 50 per cent must be added to the average capacity of a truck if it is to be used for liquid transportation. I suggest that builders of trucks make a note of that point and verify it, which can be done very readily. We have found it necessary to install baffle-plates in the tanks at certain points. I think 300 gal. is about the limit for tanks, regardless of how heavy the walls are built. Baffle-plates are necessary; without them, in going around corners, the truck is likely to turn over. We have used some of our old tanks, but they were all coupled up and baffle-plates put in. People do not realize the enormous amount of pressure there is in such tanks; even the baffle-plates are torn out at times.

Engine Support

MR. BLANCHARD:—In the description of the non-flexible frame with a transverse spring at the front end, Mr. Guernsey mentioned that he changed from a three-point to a four-point engine support to obtain additional stiffness in the frame. Is the engine crankcase relied upon in any way to afford the additional rigidity?

MR. GUERNSEY:—In our construction we have always tried to mount the engine in such a way that it never can get loose and cause damage. An engine that is bolted down to the frame in the ordinary way jumps up and down and hammers things all to pieces. That is one source of vibration which is very detrimental. If it can be eliminated, something very much worthwhile will have been accomplished. In the last four or five years we have made it a practice to mount the engines with a stiff spring holding down the leg of the engine. That serves the dual purpose of permitting a slight flexing and keeping the engine tight on its foundation and preventing up-and-down vibration. When we put the engine on four-point support, it was natural that we should put the usual springs under each of the engine arms. Those springs have a capacity of 300 lb. and I never have seen any one of them rise off its seat; so, I am sure we are not getting any more than 300 lb. of strain on any one of those arms, and it is a pretty poor crankcase that will not withstand that amount.

AMERICA AS A WORLD POWER

(*Concluded from page* 142)

could give these materials to them and they could make the big guns. That was a very fine bargain. We had a navy that functioned well. The record of recent years of the navy growth shows our navy coming up to 1,000,000 tons. The largest navy on earth, that of Great Britain, was a little short of 3,000,000 tons. Germany was next. The war came. When the British, United States, Japanese, Russian, French and Italian navies were combined, Germany had to keep her navy in safe waters.

Transportation

We had no lessons to learn from the outside world when it came to transportation. Because of our network or railroads every farm and every factory in this whole land could get its materials into service without delay. That was exactly what happened. Think how Russia and some of the other Allies were handicapped. The world's growth in railroads shows that the United States, beginning at zero in 1840, has risen to first place as usual; the next greatest nation is Russia; then come Germany and France, Great Britain and Italy. It is not fair to compare our railroad mileage with theirs individually. We ought to compare ours with that of Europe. We could serve and are in a position to serve. One of the Baldwin monster locomotives is typical of our equipment. It consists of two engines combined into one, being equipped with 24 drive-wheels and jointed in the middle so it can go around a curve. Oil is used as fuel and two men run the engine. It will draw more than three times as large a load as the largest ordinary locomotive ever built. Before we had been in France 11 months we had built railroads from Brest and Bordeaux on the west to the mountains on the east, a mileage greater than the entire Erie system.

We learned that war is business, and that back of the fighting men all the industries of the Country must be organized to serve the one purpose of winning the war. Therefore, the leaders in all these lines were called upon. A legion of scientific men came forward to solve problems in mathematics, chemistry, physics, electricity and engineering. Now the problems of peace arise, more difficult to solve than those of war. As owners of nearly one-half the significant mineral resources of the world and almost half of the present wealth of the world, we find ourselves loaded with a great responsibility. May we realize earnestly that the ownership of large wealth carries with it large responsibilities and that those responsibilities cannot be evaded. Let us remember what are the material foundations out of which world war is made, and that there are just four nations that can make or prevent world war. Let us see to it that we have a square deal for three parties at home; first for capital, second for labor and third for *the rest of us*. America is great enough to be just; America is great enough to be generous. May we use our great opportunities and powers wisely, so that, as a world power, we shall deserve the respect and gratitude of all men for all times.

The Need for Federal Control in Commercial Aviation

By S. H. PHILBIN[1]

SEMI-ANNUAL MEETING PAPER

COMMERCIAL aviation in the United States is to-day in imperative need of adequate control by Federal legislation. Its situation and necessities will first be outlined and then there will be suggested a plan of legislation which appears to be well suited to meet its present and future requirements. As a preface, it will be helpful to consider briefly certain legal principles applicable to aviation. There are certain fundamental legal principles which will control the courts in deciding the many interesting and complicated problems which will occur in aviation. It is sufficient here to indicate their nature, without attempting to discuss them in detail.

NATIONAL, STATE AND PRIVATE RIGHTS

The right of a nation to control the passage of aircraft over it has sometimes been doubted, but it seems perfectly clear that a nation has the unqualified right to prohibit or license the aircraft of other nations. The exercise of this right will depend upon international considerations of comity and convenience. The United States can forbid the aircraft of other nations from passing over its territory, and this view is now commonly accepted.[2]

Each State of the United States has full power to control and regulate aircraft within its limits, until Congress has exercised its constitutional power "to regulate commerce with foreign nations, and among the several States, and with the Indian tribes."[3] This right of the States is well illustrated by the case of Kane versus State of New Jersey,[4] where a State statute required non-resident owners of motor vehicles to appoint a State official upon whom process could be served and also required the payment of a registration fee, and the statute was sustained by the Supreme Court. These powers of the States cease when Congress speaks.

The question of what is interstate commerce has been before the courts a very great number of times and precedents of great value to air law have been established. To illustrate the length to which the courts have gone in holding that interstate commerce was involved, the recent case of New York Central Railroad Co. versus Porter,[5] held that an employe shoveling snow between tracks used in interstate and intrastate traffic and there killed was engaged in interstate commerce. It seems clear that Congress has jurisdiction to enact legislation covering not only aircraft engaged in flying between States, but also aircraft which, although solely within one State, may interfere with aircraft engaged in interstate or governmental business. The State and the Federal courts would have concurrent jurisdiction over all questions arising out of legislation applicable to aircraft. Any suit arising under such Federal legislation could be brought either in the State court or in the Federal court. If brought in the State court it could be removed to the Federal court.[6]

The two most interesting questions of private rights are (*a*) whether the landowner owns or possesses "usque ad coelum" and has such a right in the air space above the land as to be able to prohibit others from flying above his property; (*b*) whether there is an absolute liability upon the part of owners and operators of aircraft for persons and freight carried; and (*c*) what is the liability of aircraft owners and operators for damage done to private property in landing or falling. It is sufficient for present purposes merely to indicate these questions and to state that the best opinion is that the landowner cannot prohibit aircraft from passing over his land but can restrain them from flying so low or being so noisy as to constitute a nuisance. The same well considered opinion is also to the effect that while the liabilities of owners and operators of aircraft will not be absolute, yet they will be held to such a high degree of care in manufacture, inspection and operation that their liabilities, as a practical matter, will not fall very far short of being absolute.

THE IMPORTANCE OF COMMERCIAL AVIATION

The United States must have a strong, well organized and self-sufficient aviation industry for two essential reasons, military purposes and commercial development. To-day every nation in the world realizes how necessary its military and civil aviation forces are to its safety and welfare. England, France, Japan and Italy are heavily subsidizing their manufacturing and transportation services in order that they may be prepared for the coming military and commercial struggles for air supremacy. No nation can have an adequate air-force in time of war unless it has in time of peace a strong, well developed and efficient commercial industry. Such an industry greatly diminishes the need in time of peace for strictly military equipment, as well as makes possible the production of aircraft for the Government upon a less expensive basis, because of the fact that such production is in quantity. Furthermore, the entire commercial industry, with its aircraft, personnel, landing-fields, airports for seaplanes and flying-boats, and manufacturing and maintenance facilities would be immediately available to the Government.

Commerce involves communication and transportation. Unless a country makes full use of all of its available methods of communication and transportation, it cannot fully develop its commerce. Speed has always been one of the most important factors in commerce and the prog-

[1] Lawyer, New York City.

[2] See Law of the Air by H. D. Hazeltine, p. 52; Aircraft in Peace and the Law by J. M. Spaight, p. 10.

[3] See Constitution of the United States, article 1, section 8.

[4] See United States Supreme Court Reports, vol. 242, p. 160.

[5] See United States Supreme Court Reports, vol. 249, p. 168.

[6] See Constitution of the United States, article 3, section 2; Judicial Code, chapter 2, section 1.

ress of civilization has invariably been from the slow and safer to the faster and, what at first seemed, more insecure means of transportation. Walking, using horses, railroads, automobiles, aircraft, each method was more dangerous than its predecessor, especially at the outset, but as it saved time, it became necessary, and then, popular. The necessary character of aviation is now universally conceded, but it has not yet reached the popular stage due to the still existent feeling that it is solely a war machine, as well as to the high price of aircraft. The latter reason is largely dependent upon the former and as soon as the demand warrants quantity production, aircraft will not cost much more than automobiles. The period of quantity production has not yet come and aviation to-day is where the automobile industry was in 1904. It is ready to develop rapidly in this country under proper stimulus, or to atrophy and pass to other more far-sighted nations if such stimulus is lacking.

One needed stimulus is the provision of landing-fields and similar essential facilities, just as in the case of automobiles road development was a prerequisite to general use. But it must be remembered that the pilot is even more embarrassed by landing in a cornfield than the automobilist was by encountering a muddy country road. For the pilot has no right in the cornfield, and so is responsible for damages to others. Also, he risks life as well as his plane, whereas the automobilist risked a long walk and a few dollars for a team of oxen. It is obvious that the development of landing-fields is essential to the popular use of aircraft. The resources of the United States can be developed and conserved very much further by aviation, and it is of the utmost importance that nothing should be done to injure it but, on the contrary, that it should receive only encouragement.

The Situation in the United States

Commercial aviation is within the scope of this paper and military aviation is not. The matters relating to the control and operation of the Army and Navy Air Forces involve broad issues of national defense and strategy. They are too specialized and complex to be dealt with here. The same is true of the Post Office, Forestry and other Government Departments. Any sufficient consideration of them would be too lengthy for this paper. However, there can be no question that some change should be made in the organization of the various governmental departments which have to do with aviation. For example, aviation is now within the jurisdiction of the Combat Services in the War Department; the Bureaus of Navigation, of Construction and Repair and of Engineering of the Navy Department; the Aerial Mail Division of the Post Office Department; the Bureau of Standards, in the Department of Commerce; the Weather Bureau, in the Department of Agriculture; the Smithsonian Institution and the National Advisory Committee for Aeronautics. The functions of these various bodies might well be simplified and combined.

There are some 2000 airplanes in this country and the average number in daily use is about 1500. During 1920 probably about 6000 miles was flown and about 200,000 passengers carried. These estimates are based upon the records furnished by 87 aerial-transport companies. They would be more accurate if every airplane in use was required to be licensed and registered. Commercial aviation is chiefly devoted to the transport of mail, passengers and freight, but is also largely employed for such important services as surveying, forest-fire patrol, timber cruising and photography.

Inspection and Examination

Aviation closely affects the general interests of the community at large. A defective aircraft or an unskilled pilot may expose to danger persons and property not in the aircraft, just as a passing freight-car or ship loaded with explosives or a careless automobile driver might injure the innocent bystander. Danger from others is inherent in community life, but such danger can be minimized. An adequate system of inspection and licensing aircraft, operators of aircraft and landing-fields would remove practically all of the danger in commercial flying. An airplane is unquestionably a dangerous instrumentality and it is useless to endeavor to think of it as anything else. Speed connotes danger. A mass of some 5000 or 10,000 lb. moving at a velocity of 80 to 120 m.p.h. is characteristically capable of accomplishing tremendous destruction. This is as true of an airplane as it is of a train running through a busy switch-yard, a ship coming into a foggy crowded harbor or a high-powered automobile in a street full of pedestrians and vehicles. Moreover, an airplane cannot stop or slow down in case of trouble. It must go on to sustain itself. If it cannot reach the nearest landing-field, greater or lesser damage is almost certain to result. If the design of the structure of an aircraft is wrong, if an important part is carelessly made, or if unsuitable material is employed, great loss of life and property damage may result. This risk must be reduced to a minimum. All aircraft should be compelled to undergo inspection and test for airworthiness before they are allowed to take the air and should thereafter be subject to periodical inspections.

The engineer of a train, the navigator of a ship and the pilot of an airplane each have a tremendous responsibility. A physical defect or mental weakness may cause great destruction. Railroad trains, ships, airplanes and automobiles cannot be discarded because they are dangerous instrumentalities but, on the other hand, the public is entitled to the greatest possible protection and should be given every guarantee that those using these dangerous instrumentalities are fit to do so. Locomotive engineers, navigators and others similarly responsible must pass examinations before they are entrusted with their duties. Operators of aircraft, including pilots and engineers, should be compelled to qualify as such, to take out licenses and to be subject to periodic examinations.

Landing-Fields

Aviation must have landing-fields sufficient in number and character. Safety and convenience in flying depend directly upon aircraft being able to come to the ground on a safe, accessible and well-equipped landing-field, where supplies can be obtained readily and passengers and freight can be transferred easily. If there is no adequate landing-field within gliding distance there may be a certain amount of risk involved, if it becomes necessary for the aircraft to descend because of an unexpected thunderstorm or other emergency. The accessibility of the landing-field is obviously of great importance. A field far removed from the transportation facilities of rail and water communications would be exceedingly inconvenient and of comparatively little value. The management and operation of landing-fields can vary greatly between maximum and minimum efficiency, and unless there is some supervision exercised over them it is quite possible that the unsafe and inefficient ones will predominate. There must be enough landing-fields in this coun-

try and they must conform with certain standards unless the commercial progress of aviation is to be hampered and delayed.

Air-Routes and Rules of the Air

Air-routes are a natural growth of commercial aviation. Their location and nature are controlled mainly by the prospective traffic-density and by the adequacy of terminal facilities, that is, landing-fields. There are other considerations of varying importance, such as the nature of prevailing winds and other meteorological factors, altitudes, etc., but the two first mentioned are the controlling ones. Air-routes are of vital importance to the Nation in time of war. It must be able to mobilize quickly its airplanes and utilize them at points of strategic importance. This is impossible unless air-routes and landing-fields, with their trained personnel and necessary facilities, are in existence as commercial practicalities throughout this country. Commercial and strategic air-routes correspond in the United States. They must be properly laid out by competent authority.

Rules of the air are clearly necessary to avoid collisions and confusion. The respective rights of aircraft meeting or overtaking each other, whether airplane or dirigible or both; what shall be the priority in taking-off or landing; what lights shall be carried and how, and a great many other similar matters should be determined and made binding upon all aircraft. Otherwise, unnecessary accidents will occur with ensuing damage to aircraft, their contents and what is beneath them. Rules and regulations are requisite also to prevent low flying or acrobatics over populated districts. Such regulations are in force in other countries. They are in force in some towns and cities here but, as they are not uniform, they should be superseded by Federal regulations which would be uniform everywhere.

Aeronautical Safety Code

Insurance of aircraft and personnel is necessary before full commercial development can be attained. It is as true of the aviation industry as of other industries that the individual cannot afford to be uninsured. Full insurance protection in aviation with a reasonable system of rates cannot be had until there is proper Federal control.

In consideration of the foregoing matters, we must not omit reference to the fact that the art of aeronautics is not yet standardized. It is undergoing constant improvement, based upon laborious and costly scientific investigations, which will undoubtedly continue for some years. Its individual and peculiar arrangements can only be met satisfactorily by a flexible set of rules and regulations, composed and administered by capable and experienced persons. A new discovery may render obsolete in a week rules which, if allowed to remain unchanged, would immeasurably interfere with the progress of the art and industry. No rules or regulations should be enacted until careful consideration has been given to the needs of the complex and difficult situation and those interested have had an opportunity to present their views.

It is important to note that the Bureau of Standards has already prepared a partial tentative draft of an American Aeronautical Safety Code, containing a thorough, well-laid-out plan of safety regulations. Airplanes, aviators, powerplants, signals, traffic and flying rules and landing-fields are given detailed and able consideration. This draft is being considered by a committee of this Society and, when issued in final form under the auspices of the various organizations interested in aeronautics, will unquestionably be a most valuable contribution to the art and industry.

The Character of the Administrative Body

The particular legal status of the body which should formulate and administer the necessary rules and regulations and provide for the licensing of aircraft, operators and landing-fields does not seem to be essential, provided it is competent and authoritative. It may conceivably be a separate board, such as the Shipping Board or Federal Trade Board. This is the Canadian organization. It may be a Secretary of Civil Aviation, as is the case in England, or it may be a sub-department in an existing department, such as the Department of Commerce. Each of these possibilities has been suggested and each has its individual merits and defects.

The fundamental question appears to be, not what shall be the title of the two or three men who will actually do the work, but rather what will be their ability, powers and functions. It is the purpose of this paper only to indicate what powers and functions a suitable body should have, regardless of the form or title it may take. It is essential, of course, that it should be vested with sufficient authority and responsibility to enable it to make its own decisions and enforce its own policies without being compelled to seek the approval of any other department or board. It must be able to stand on its own feet or it will not be able to accomplish anything constructive or desirable, and only hopeless confusion will result. It is highly desirable that the Army, the Navy, the Post Office and the Department of Commerce should be actively represented. Each of these departments is vitally concerned with the welfare of commercial aviation and is also in a position to further greatly its interests. They should be in a position to present their views directly and effectively to the controlling body.

Nature and Scope of Immediate Federal Legislation

A body should be immediately constituted by Act of Congress, which for convenience will be referred to herein as a Board, which should have the authority to

(1) Investigate, from time to time, aviation conditions in and with foreign countries, appoint representatives at such international aerial conferences as to the Board may seem advisable, and report to Congress thereon with such recommendations as seem advisable
(2) Establish or supervise aircraft routes and ways and the regulations which shall govern the traveling of such routes and ways
(3) Grant or refuse licenses for aircraft in response to a written application therefor which shall set forth the data requested by the Board
(4) Grant or refuse operators' licenses to pilots, engineers or other operators of aircraft in response to a written application therefor which shall set forth the data requested by the Board
(5) Grant or refuse landing-field licenses in response to a written application therefor which shall set forth the data requested by the Board
(6) Revoke licenses for aircraft, operators or landing-fields upon determination by the Board that its requirements and standards are not being complied with
(7) Make all necessary rules and regulations to carry out the above provisions

Licenses for aircraft, operators or landing-fields should

not be granted unless the Board considers that the applicants meet the requisite tests. Suitable penalties should be provided for the operation of unlicensed aircraft or landing-fields and for violating any of the rules and regulations of the Board with respect to air-routes or other matters. Privileges should be granted to foreign aircraft and operators in the discretion of the Board, provided their nations extend similar privileges to licensed American aircraft and operators.

It sometimes occurs that commercial aircraft are compelled in an emergency to land on or near a military or naval landing-field. Because of the vital importance of commercial aviation to the safety of the country, the Secretaries of War and the Navy should be authorized to sell such gasoline, oil and other aircraft supplies as can be spared without detriment to the military service at not less than the contract price plus 25 per cent to cover the cost of purchase and inspection.

The constitutionality of the proposed legislation has been carefully examined and it is the opinion of eminent lawyers that it would be constitutional. A broader plan might or might not be and might also cause opposition, which would delay and perhaps seriously interfere with the enactment of the desired Federal legislation. The essential thing is to make a beginning and then expand as experience teaches. The art is still too much in the growing period to call for a fixed system.

The International Aerial Convention of Oct. 13, 1919, has fallen with the League of Nations, of which it was a part. It is still of some importance, however, as it is proposed to hold a meeting of aviation representatives of the allied and associated powers in London this year, to consider aeronautic matters, and the question will be suggested as to whether the United States should join this part of the League of Nations. It is not within the scope of this paper to consider this matter. Nevertheless, it may be pointed out that the conditions in the United States are essentially different from those in England, France, Italy or other continental nations where the national boundaries are limited and aircraft are constantly passing from friendly to neutral or hostile countries. An elaborate system of navigation rules, customs regulations and other legislation is neither necessary nor desirable in the United States. So far as possible, the rules and regulations in this country should conform to the standard practice abroad, but it is obviously highly undesirable that commercial aviation in the United States should be controlled by an International Commission for Air Navigation, probably sitting at Geneva, and in which the United States would have a small minority voice.

In conclusion, it must be repeated that there is urgent necessity to-day of a carefully formulated and well-administered plan of Federal legislation, which will take care of the immediate and future requirements of the vitally important and fast-developing aviation industry.

Viscosity

IF a bucketful of water is tipped until the water is about to spill and then suddenly released so that it will resume its horizontal position, the water will oscillate from side to side. Each oscillation will be of less and less amplitude until the water is finally at rest with its surface horizontal. If the same experiment be tried with an engine oil it will be found to come to rest much sooner than did the water. If this experiment is repeated with a cylinder oil the liquid will come to rest with practically no oscillation at all. In all cases the oscillation ceases sooner or later and it is the internal friction or viscosity of the liquid that stops the motion. In other words, although liquids can be made to assume any shape they offer a certain internal resistance to being moved or disturbed and this is the property, called viscosity, that interests us.

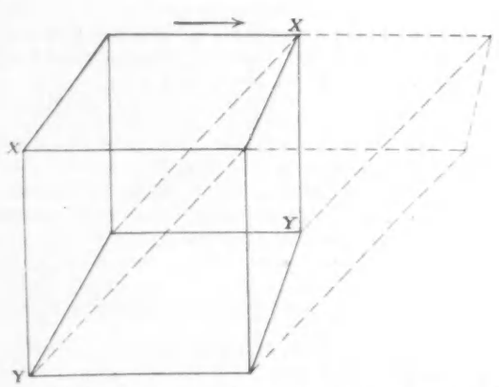


DIAGRAM SHOWING HOW FORCE CAN BE EMPLOYED TO MEASURE THE ABSOLUTE VISCOSITY OF A LIQUID

There are many ways of measuring viscosity in liquids. The purely scientific way is to determine the absolute viscosity of the liquid. The absolute viscosity of a liquid can be explained as follows: In the accompanying illustration let *XX* and *YY* be two plane surfaces a given distance apart and between the two surfaces is placed the liquid, the absolute viscosity of which it is desired to measure. The surface *YY* is kept stationary and the surface *XX* moved at a given velocity in the direction of the arrow so that it will, after a time, assume the position shown dotted. The force required to maintain this motion, that is, the force required to distort the liquid at this rate is a measure of the absolute viscosity. If the surfaces *XX* and *YY* are each 1 sq. cm. (0.155 sq. in.) in area and 1 cm. (0.3937 in.) apart and the surface *XX* is moved at a velocity of 1 cm. (0.3937 in.) per sec., the force in dynes required to maintain this rate of motion is the absolute viscosity. The unit of absolute viscosity is called a "poise."

It is much easier to measure the flow of a liquid through a pipe by noting the time required for a certain quantity of liquid to pass. There has been developed a formula giving the relation between the absolute viscosity of a liquid and the quantity discharged through a tube of small diameter. Many practical instruments for measuring viscosity have been proposed. The three of greatest importance in oil measurements, however, all depend on the time it takes a given quantity of oil to flow through a certain sized orifice of a tube. They are the Redwood instrument used largely in England, the Engler used in Germany and sometimes in the United States, and the Saybolt used by a large number of the oil companies operating in this country.—J. Maris in *Petroleum Magazine*.

Cooperation in Research

By Walter E. Lay[1]

Semi-Annual Meeting Paper *Illustrated with* Photographs and Drawings

DURING the war research and scientific investigation of everything having a possible relation to the great conflict were conducted on a scale never before attempted. The war has been called the war of engineers and scientists. It might well be called the war of the automotive industries, in which development work was particularly intense. Now that the big problem has apparently been solved there is no less a need for continued work of this nature. It is true, of course, that in the reconstruction period the most rigid economy is necessary. But research work carried on with the full utilization of all present facilities will ultimately be an economy. It always has been an economy ultimately.

From time immemorial the seat of learning, the school, has been also the center of research. Gradually through the painstaking efforts of men at educational centers has the complex mass of known facts been gathered, arranged and classified to form the body of what we call the sciences. It is necessary for every modern scientific school or college to maintain laboratories where work can be done by the student, which proves how certain principles and theories hold true and also shows him their limitations in practical application. There is in the United States a large quantity of such equipment available for accurate scientific investigation and in most cases it is now being used in that way. There have also grown up in various industries large and very completely equipped laboratories. In the case of the automotive industry their work has been a very important factor in the phenomenally rapid development of the automobile.

Industrial and Technical School Research

There seems to be a fundamental difference between industrial and technical school laboratory work. The reason for this can be traced back to the incentive behind the endeavor. The work done in an industrial research laboratory is carried on with the idea of immediate improvement of the product or the development of new products. At the college laboratory the incentive is often purely a desire to explore which finds expression more or less in the work of any human being. Too often this work has been done without taking into consideration whether it would have an immediate practical application or indeed ever prove of value to mankind. However, it will be admitted that in general the work is done in a thorough and conclusive manner. The university, at which every one is searching for knowledge, has an atmosphere conducive to the complete solution of problems in all their details. The work is carried on in a manner at once painstaking and accurate without serious interference or time limit and should give results conclusive beyond question.

In the experimental laboratory real research is carried on but there is always a tendency to side-track it to give way for makeshifts which will temporarily satisfy the demands of the public or the sales force and return a satisfactory profit. Seldom indeed can the engineer attack a problem, carry out his investigation until all possibilities have been exhausted, and bring the work to a successful conclusion. There are some types of work which can best be done in an industrial laboratory and probably will always be done there. On the other hand, some research work can very properly be done at the laboratories of our universities and technical colleges. When so many different laboratories are engaged on similar or related problems, one would think that considerable economy of effort could be effected by a proper coordination of the work done by both industrial and school laboratories. It might be somewhat difficult for a central organization to direct the procedure, but much good could be accomplished by keeping each organization acquainted with the equipment developed and the current results obtained by the others.

There are general investigations which can be taken up by the industry as a whole and it is perhaps this kind of subject that can be handled best in a laboratory of a State university or technical college. The University of Michigan by virtue of its location in the center of the automobile industry should be among those considered for work along these lines. The accompanying statistics taken from *Automotive Industries*[2] on the distribution of automobile and truck builders will help to make this clear. In the same magazine the daily production of cars by the leading motor-car builders in August, 1919, was reported. Twenty-six of the 34 listed were located in Michigan and had a total daily production of 5574 cars or approximately 1,670,000 for the year. As the year's production for the whole United States was under 2,000,000, Michigan produced more than three-fourths of the automobiles built in the United States for the year 1919.

Distribution of Automobile and Truck Builders

State	Automobile Builders Number	Automobile Builders Rank in United States	Truck Builders Number	Truck Builders Rank in United States
Michigan	34	1	53	1
Ohio	25	2	32	3
Illinois	16	4	40	2
Indiana	20	3	13	6
Total for group	95		138	
Total for United States	167		300	
Percentage in group	57		46	
Percentage in Michigan	20		18	

Automobile Laboratory at University of Michigan

There has been at the University a gradual development of laboratories and equipment for use in teaching engineering science with particular reference to its application to problems met in the design and operation of automotive vehicles. Among these is the automobile division of the mechanical laboratory. This section quickly

[1] M. S. A. E.—Assistant professor of mechanical engineering in charge of automobile engineering, University of Michigan, Ann Arbor, Mich.

[2] See *Automotive Industries*, Aug. 28, 1919, p. 406.

outgrew the space allowed in the main laboratory and this year moved into one of the cantonment type of buildings used for training army mechanics during the war, occupying a floor-space 60 x 120 ft.

This laboratory is divided into three sections, a classroom, a general laboratory for routine testing and demonstration which is shown in Fig. 1 and a research room where accurate mechanical testing and investigations can be carried out. The classroom is supplied with tables, charts and data books needed in computing the results of experimental tests. The second section is equipped with seven engine testing-stands and three water-dynamometers of from 20 to 60-hp. capacity and one calibrated fan-brake.

The water-dynamometers are mounted on a track so that they can be easily moved to position at the rear of any engine where they are fastened in approximate alignment by two holding-down tee-bolts. The dynamometer

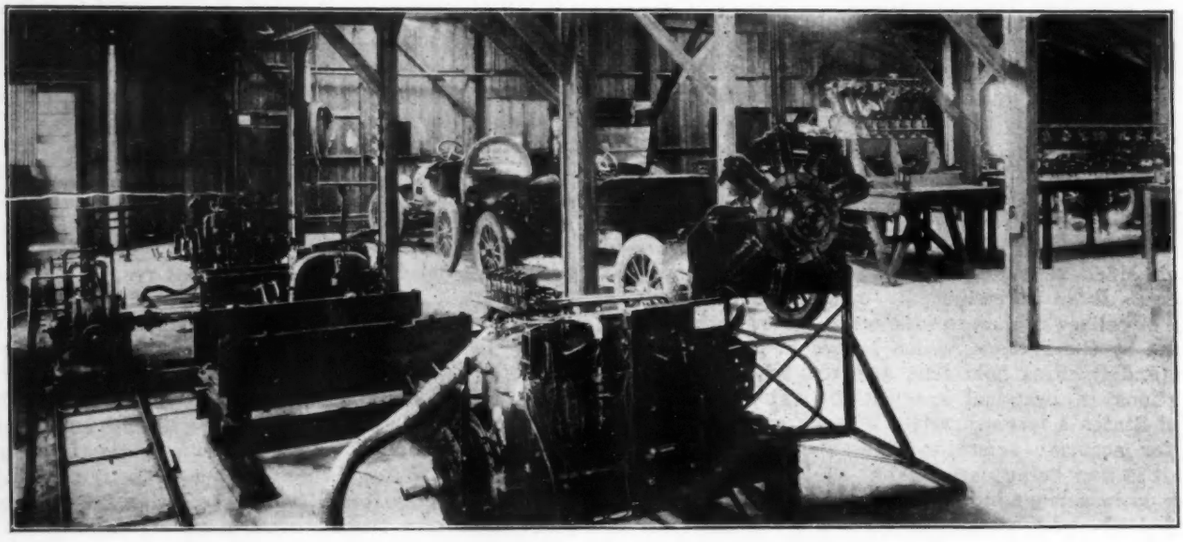


FIG. 1—GENERAL AUTOMOBILE TESTING LABORATORY

is connected to the engine by a drive-shaft with two metal universal-joints. The shaft is splined at both ends. Both engines and dynamometers are fitted with the same universal-joint unit which is fitted to receive the splined ends of the shaft. To disconnect the dynamometer from the engine it is necessary to loosen the holding-down bolts and move the dynamometer down the track until one universal-joint slides free from the shaft. Then the shaft can be removed entirely and held ready to go into place as the dynamometer is aligned with the next engine. Water for cooling the engines and the dynamometers is furnished through two pipes on the wall, one supplying cold water and the other water at any desired temperature from cold to near the boiling-point. If the engine is air-cooled conditions similar to those in operation on the road are obtained by use of a portable Sirocco blower driven by a direct-connected electric motor. Fuel is supplied from 10-gal. tanks mounted on light stands supplied with large casters so that they can be rolled to the gasoline pumps for refilling when necessary.

There are available for demonstration and tests over 20 engines varying in size from the Ford to the Liberty aviation engine. Two chassis are used for car-performance tests including hill-climbing, acceleration and economy of fuel over the driving range. In addition, there is mounted on demonstrating racks considerable equipment, including carbureters, ignition systems, governors, clutches, transmissions and rear axles.

The third section, the research room, includes among its larger equipment a 100-hp. and a 60-hp. electric dynamometer, a set of chassis testing drums, a drawbar pull dynamometer and a motor-generator set. The dynamometers are fully equipped with switchboards, load resistances, control rheostats, beam-scales, tachometers and electrically operated revolution-counters to be used in conjunction with the fuel measuring apparatus. The important feature of this room is the layout of the dynamometers and testing-floor to use the dynamometers to their full capacity as shown in Fig. 2. It had been found in previous years that when a complicated set-up had been built up for special work the dynamometer could not be used for any other work without tearing down the set-up and making a new one. So when the new laboratory was laid out the pedestals of the dynamometer were mounted in a flat circular bedplate or base with a circular groove on its under surface. A similar base was set in the concrete with a corresponding groove in its upper surface. These grooves are filled with ¾-in. steel balls and form a bearing upon which the dynamometer can be turned to align its shaft with any one of the four testing-bases or the countershaft driven by the chassis drums. The dynamometer is located exactly by two dowel pins directly under its shaft. The relative position of the dynamometer and engine bases is illustrated in Fig. 3.

Metal universal-joints and a drive-shaft splined at both ends are used here as well as on the water-brakes. As the dynamometer is rotated on its base, the distance between the universal-joint on the dynamometer and that on the engine is increased until one splined end of the shaft comes free from its universal-joint. The shaft can then be readily removed and placed in position on another engine so that it goes into place as the dynamometer is brought into alignment with it. Thus the dynamometer can be disconnected from one engine and connected to another in 5 or 10 min.

The chassis-testing outfit, which has not been put in place, consists essentially of two drums, having a wood surface 6 ft. in diameter and 18 in. wide, which are mounted on large shafts at the proper distance apart to

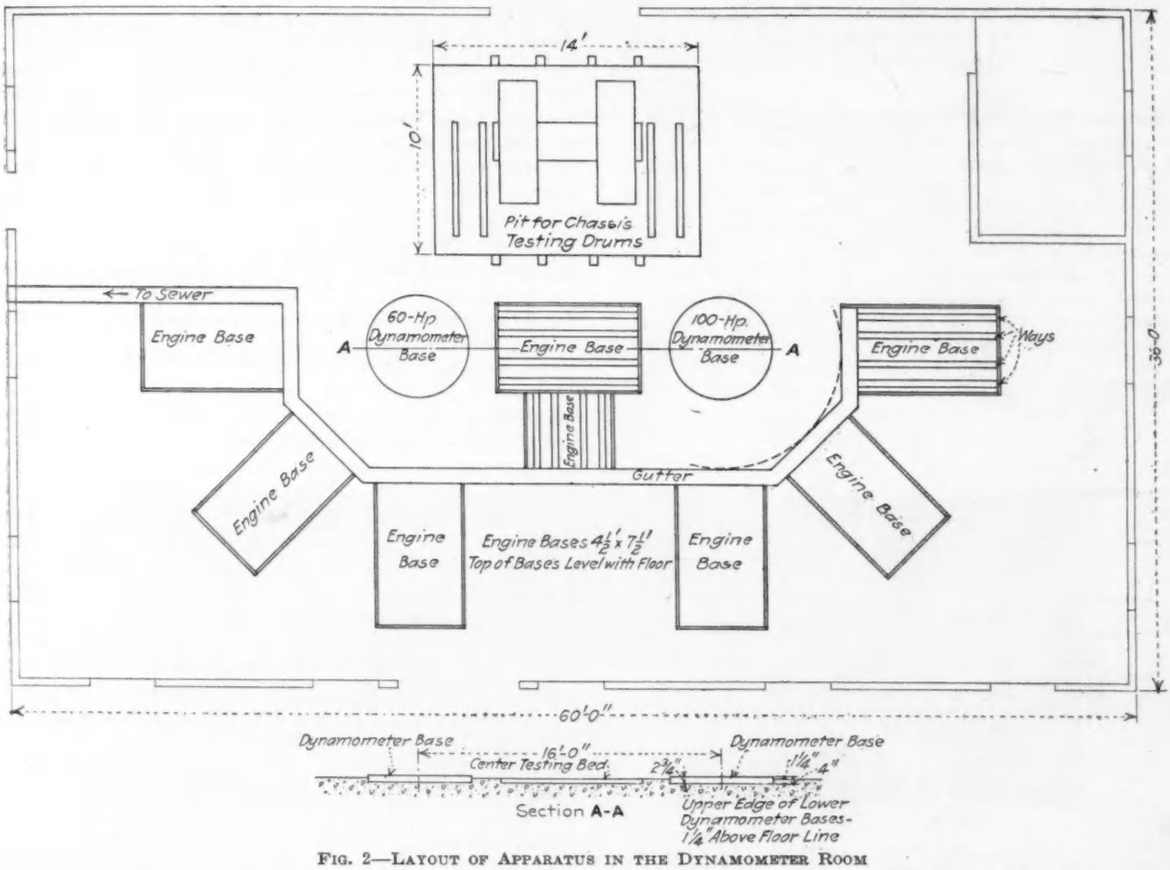


FIG. 2—LAYOUT OF APPARATUS IN THE DYNAMOMETER ROOM

correspond with the track of an automobile. The outer end of each shaft is splined and will fit the axle drive-gears of a 5-ton truck differential-carrier assembly in place of an axle-shaft. This in turn will drive a heavy gearset which drives the dynamometer through silent chains as outlined in Fig. 4. The dynamometers can thus be driven at the same speed as the engine and easily absorb the output. The net power-output of a chassis can be determined by measuring the pull of the car with a drawbar dynamometer and determining the peripheral speed of the drums.

The motor-generator set is used to furnish direct current to operate the electric dynamometers. The motor, being of the synchronous type, is not affected by variations of voltage and will maintain a constant speed of the electric generator and a constant voltage at the dynamometer switchboard.

Among the more interesting details might be men-

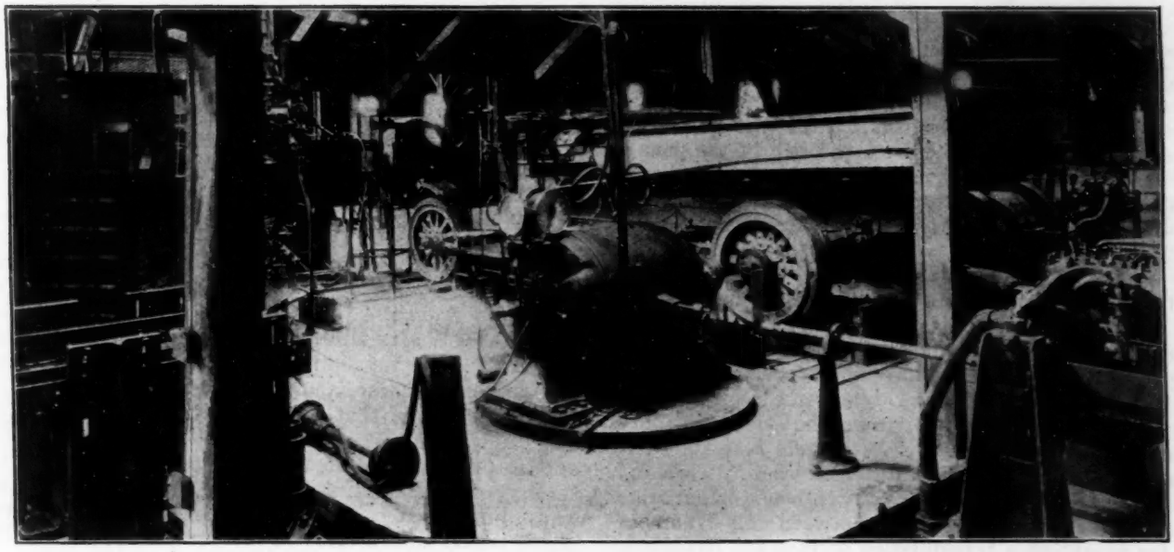


FIG. 3—DETERMINING THE EFFICIENCY OF THE TRANSMISSION SYSTEM IN THE DYNAMOMETER ROOM

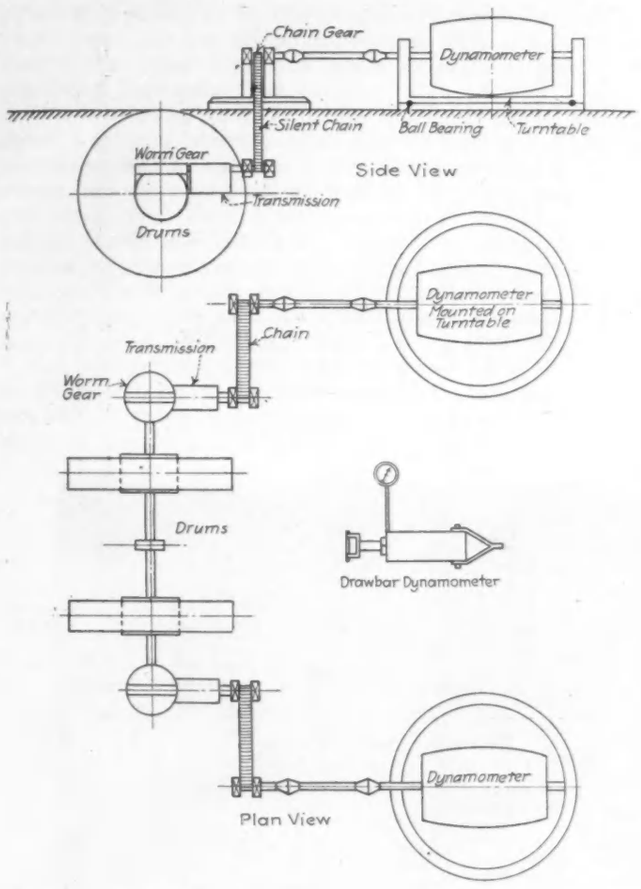


FIG. 4—CHASSIS TESTING OUTFIT

tioned the arrangement of the controls of the dynamometer and engine set-up shown in Fig. 3. In front of the scale-beam is a table supported by the dynamometer base. The field-rheostats or load and speed controls have been placed under this with the control-wheels above. A throttle and spark-control quadrant is located on the post just above the table and the large tachometer is only 2 ft. from the eyes of the operator. This brings all controls within easy reach and with the dynamometer in any of its positions the switchboard is never more than two steps from the operators' position at the control table.

The engine bases are built up of four slotted rails bolted rigidly to 2-in. angle-iron and the whole embedded in a concrete slab separated from the rest of the floor by planks. If the engine being tested develops excessive vibration, it is not communicated through the floor to the dynamometer or any of the weighing apparatus. The gutter shown between the engine and dynamometer bases carries off the water and contains the main exhaust and hot and cold-water pipes. By a suitable arrangement of valves water is delivered from the outlet through garden-hose to the engine jacket, the radiator or cooling tank at any desired temperature.

With this arrangement the dynamometer is made to serve a variety of purposes without building new parts for each test or disarranging it to such an extent that it cannot be made to handle a different kind of work in a short time. In other words, it has been made somewhat universal. There is space between the dynamometers for mounting a transmission so that one dynamometer can drive the transmission and the other absorb the output, thus measuring both the input and the output and determining the mechanical efficiency. A rear-axle can be mounted between them and driven by an engine on a reaction dynamometer so that the efficiency of the final-drive and the action of the differential can be determined. In Fig. 3 a truck is shown jacked-up with each rear-axle jackshaft connected to a dynamometer. Here the efficiency of the transmission system, including the universal-joint shafts, transmissions, final-drive, and the bearings in the differential-carrier, is being determined. There is room for six engines to be mounted at the same time. This will allow one engine to be set up while tests are being made on another if necessary.

OTHER RESEARCH EQUIPMENT

There is available for use in connection with the above-mentioned equipment special fuel-measuring devices with electrically operated revolution-counters and stop-watches, meters for measuring air and water, pyrometers, gas-analysis apparatus, a manograph, indicators and complete accessories necessary for doing accurate research work. In the study of engineering materials used in the construction of the automobile the chemical laboratories are very important. The laboratory equipment for work in metallurgy and metallography is extensive. Ample facilities are provided for the microscopic study of metals. A new photomicrographic camera is to be added.

Electric furnaces are used largely for heat-treatment of metals but there are also oil and gas-fired furnaces of various capacities. Lead pots and various salt-baths are available whenever desired. The pyrometer laboratory has a large equipment of various types of temperature-measuring device. This includes several types of thermo-electric and optical pyrometer. A platinum-rhodium thermocouple, which has been standardized recently by the Bureau of Standards, is used as an ultimate standard for maintaining all the other instruments in an accurate condition. A precision potentiometer is used in calibrating all thermocouples for use about the laboratory. For work in electrometallurgy and electrothermal studies direct and alternating-current lines are available. A specially designed switchboard and transformer make a very flexible outfit for use in constructing carbon resistor furnaces. The gas and fuel laboratories are equipped with all necessary apparatus for gas-analysis and fuel-testing. This includes several types of gas burette, bomb calorimeters and other more specialized apparatus.

In the physical testing laboratory apparatus is provided for testing the strength of materials used in engineering work. This equipment includes a 100,000-lb. Olsen testing machine and one of 200,000-lb. capacity built by Riehle Bros. Both of these machines are adapted to tensile, compressive and transverse tests and are run by direct-connected electric motors. An Olsen machine of 240,000-in-lb. capacity, also equipped with a direct-connected motor, is used in determining the torsional strength of shafts and axles. Impact tests are made on an Olsen impact-machine, and an Upton-Lewis toughness-testing machine is used for endurance tests.

It is our belief that these facilities should be utilized more fully. The Society has established a research committee and there is slowly being developed at the University of Michigan a Bureau of Industrial Research whose purpose it is to coordinate, if possible, the efforts of industrial laboratories in Michigan with those of the University.

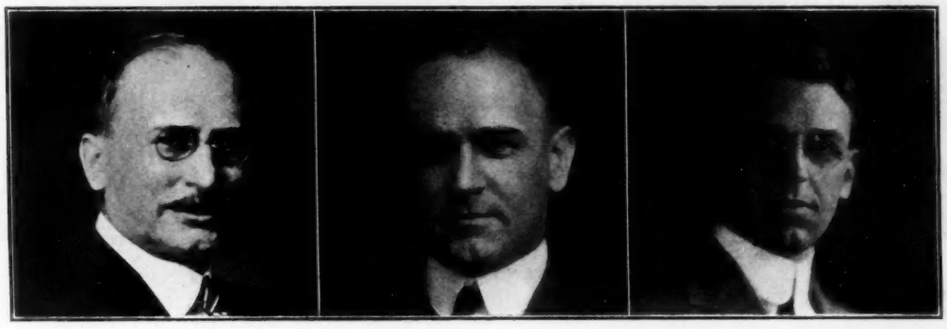
Activities of the Sections

THERE appear in this issue pictures of the officers of all of the Sections. These men assumed office in May and will direct the programs of their respective Sections for the coming year. Members do not perhaps always realize the arduous work that is done and the considerable amount of time which is devoted to it by the Section officers. The success of the Sections throughout the year will depend largely upon the support given to these officers by the other members.

The plans outlined at the Summer Meeting of the Society for arranging the schedules for the Sections early in the season are being worked out. The Dayton, Detroit, Metropolitan, Mid-West and Pennsylvania Sections have selected the subjects for most of their meetings and in some cases have secured the speakers. The remaining Sections expect to announce their plans shortly.

No technical sessions will be held until September. A number of the Sections have however arranged to hold outings during the summer. These are always popular additions to the season's program.

Last season a number of plant visits were made, including that of the Metropolitan Section to the yards of the Consolidated Shipbuilding Corporation, the Pennsylvania Section's trip to the Navy Yard at Philadelphia and the inspection of the Rolls-Royce factory at Springfield by the New England Section. Similar visits will be made by various Sections this year. Some of these will be joint meetings of Sections. An invitation has already been accepted by the Society to visit the Aberdeen Proving Ground on Oct. 7, and several of the Eastern Sections plan to take this trip in place of holding their regular October meeting. An announcement of this trip appears on page 84.



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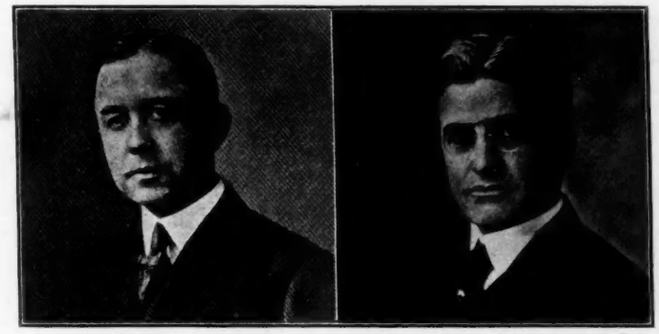

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Applicants *Qualified*

The following applicants have qualified for admission to the Society between June 10 and July 11, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ABELL, ROLLIN (M) designing engineer, Abell Valve, *Mattapan, Mass.*

ALEXANDER, C. K. (A) sales engineer, Wheeler-Schebler Carburetor Co., *Indianapolis.*

ALLEN, GEORGE B. (M) chief engineer, Liberty Motor Car Co., *Detroit,* (mail) 181 Philip Avenue.

ALVORD, C. H. (M) factory manager, Gray & Davis, Inc., *Boston.*

ANDREW, D., JR. (A) sales manager, Arco Co., *Cleveland,* (mail) 13716 Superior Road, *East Cleveland, Ohio.*

AUMENT, H. CHESTER (M) manager, parts department, Locomobile Co., Bridgeport, Conn. (mail) 101 Ocean Avenue, *Milford, Conn.*

BARRETT, WILLIAM F. (A) vice-president, Prest-O-Lite Co., Inc., 30 East 42nd Street, *New York City.*

BARTLETT, LEROY A. (A) factory representative, Detroit Steel Products Co., *Detroit.*

BASKERVILLE, DEAN E. (M) automotive body engineer, Dodge Bros., *Detroit,* (mail) 1455 Field Avenue.

BECH, C. O. (A) engineer, Texas Co., New York City, (mail) 29 First Street, *Weehawken, N. J.*

BECK, CHARLES EDGAR (A) sales engineer, Busch-Sulzer Bros. Diesel Engine Co., St. Louis, (mail) 3605 Central Street, *Kansas City, Mo.*

BLACKMORE, LLOYD (A) patent attorney, General Motors Corporation, *Detroit.*

BLANCHARD, HARRY G. (M) factory manager, Coast Tire & Rubber Co., 50th Avenue and 12th Street, *Oakland, Cal.*

BLUM, LOUIS E., JR. (J) mechanical draftsman and designer, Splitdorf Electrical Co., *Newark, N. J.,* (mail) 607 South 19th Street.

BRADLEY, JOHN J., JR. (A) chief stock chaser in machine shop, Continental Motors Corporation, *Detroit,* (mail) 1404 East Jefferson Avenue.

BREWER, JOHN W. (M) manager, pricing department, International Motor Co., New York City, (mail) 313 West 92nd Street.

BROPHY, J. W. (J) assistant production superintendent, Remy electric division, General Motor Corporation, *Anderson, Ind.,* (mail) 1620 Fletcher Street.

BRUNSWICK BALKE COLLENDER CO., (Aff) *Chicago.*
Representative:
Miller, J. O., assistant factory superintendent.

BURCH, FERDINAND L. (A) engineer, Standard Automotive Corporation, Mooresville, Ind., (mail) 826 Fort Wayne Avenue, *Indianapolis.*

BURTON, EWART E. (J) mechanical draftsman, Union Oil Co., Los Angeles, (Mail) 51 Park Avenue, *Venice, Cal.*

CALDWELL, WILLIAM E. (A) assistant manager of sales, Cleveland Twist Drill Co., 1242 East 49th Street, *Cleveland.*

CAMINEZ, HAROLD (J) aeronautical designer, Air Service, McCook Field, *Dayton, Ohio.*

CARPENTER, W. W. (A) sales engineer, H. H. Knepper, 4835 Woodward Avenue, *Detroit.*

CARR, MOSES FRANCIS (A) assistant general manager, Carr Fastener Co., 31 Ames Street, *Cambridge, Mass.*

CARVELLI, GUSTAF (M) designing engineer, Curtiss Aeroplane & Motor Corporation, Garden City, N. Y., (mail) 271 Hicks Street, *Brooklyn, N. Y.*

CARVER, W. L. (M) general manager and chief engineer, Antigo Tractor Corporation, *Antigo, Wis.*

CHASE, EUGENE P. (M) 21 Ocean Avenue, *Milford, Conn.*

CHUCAN, JOHN (M) mechanical engineer, Goodwin Car & Mfg. Co., Inc., *Chicago,* (mail) P. O. Box 112.

COLE, C. WARREN (E S) 346 Bridge Street, *Grand Rapids, Mich.*

COLE, WALTER C. (A) vice-president and general manager, Wm. N. Albee Co., Marquette Building, *Detroit.*

CUMMINGS, STANLEY R. (J) instructor in mechanical engineering, Massachusetts Institute of Technology, Cambridge, Mass., (mail) 388 Highland Avenue, *Wollaston, Mass.*

CURRIE, CARLETON H. (J) department assistant in drafting and machine shop, mechanical engineering department, Michigan Agricultural College, East Lansing, Mich., (mail) R. F. D. No. 5, *Grand Ledge, Mich.*

DANFORTH, I. W. (A) sales manager, Gabriel Mfg. Co., 1407 East 40th Street, *Cleveland.*

DAVIS, JAMES H. (A) farm engineer, General Motors Research Corporation, *Dayton, Ohio.*

DISBROW, LIVINGSTON (J) *Norwalk, Conn.*

DRAKE, HARCOURT C. (M) engineer, Sperry Gyroscope Co., Brooklyn, N. Y., (mail) 8542 91st Street, *Woodhaven, N. Y.*

DUESENBERG, WESLEY C. (A) Duesenberg Motor & Car Co., Indianapolis, (mail) 1810 Pratt Boulevard, *Chicago.*

EDELEN, JAMES L., (M) designer, Moon Motor Car Co., *St. Louis* (mail) 5457 Enright Avenue.

EDGARTON, LEWIS S. (E S) student, Massachusetts Institute of Technology, Cambridge, Mass., (mail) 455 South Fourth Street, *Fulton, N. Y.*

ELSTON, W. B. (S M) assistant chief motor engineer, Curtiss Aeroplane & Motor Corporation, Garden City, N. Y., (mail) 41 Columbia Street, *Hempstead, N. Y.*

ENOCHS, C. D. (A) vice-president, Shaw-Enochs Tractor Co., 2416 University Avenue, Southeast, *Minneapolis.*

FEEMSTER, DAVID R. (J) assistant chief engineer, Bock Bearing Co., Phillips Avenue and Michigan Central Railroad, *Toledo, Ohio.*

FIRST, HARRY V. (J) designing engineer, Root & Vandervoort Engineering Co., East Moline, Ill. (mail) 2124 Fifth Avenue, *Moline, Ill.*

FISHER, ROY R. (A) president, Ray Battery Co., *Ypsilanti, Mich.*

FORD, FREDERICK HOWE (A) electrical engineer and manager of headlight lens department, C. A. Shaler Co., *Waupun, Wis.*

FREEMAN, GEORGE W. (A) mechanical supervisor, Klinger Bros., *New York City,* (mail) 10 West 102nd Street.

FRANZBLAU, JOSEPH (A) senior automotive instructor, Army Vocational Schools, Fort Slocum, N. Y. (mail) 37 Charles Street, *New Rochelle, N. Y.*

GAFFNEY, MICHAEL W. (M) body engineer, Haynes Automobile Co., *Kokomo, Ind.,* (mail) 912 South Main Street.

GANDELOT, HOWARD K. (A) service manager, B. W. Lemmon Co., *Pittsburgh,* (mail) 523 Lincoln Avenue.

GATES, L. S. (A) president, Gates & Co., 250 West 54th Street, *New York City.*

GOTTRON, ROBERT E. (A) director of aeronautical engineering, Cleveland Engineering Laboratories Co., 1444 East 49th Street, *Cleveland.*

GRIGNARD, EMILE E. (A) New England district manager, Crew Levick Co., Philadelphia, (mail) 8 Irvington Street, *Boston.*

HAIBE, RENO (M) research engineer, Kissel Motor Car Co., *Hartford, Wis.,* (mail) 331 East Loos Street.

HANSON, WALTER M. (A) sales engineer, Geuder, Paeschke & Frey Co., Milwaukee, (mail) 712 Dime Bank Building, *Detroit.*

HASTINGS, WARREN B. (A) editor, Canadian Motorist, 607 Lumsden Building, *Toronto, Ont., Canada.*

HATHORN, CHARLES E. (A) designer, Curtiss Aeroplane & Motor Corporation, Garden City, N. Y., (mail) 22 Lafayette Avenue, *Hempstead, N. Y.*

HEDENE, EDWIN E. (J) chief draftsman, Standard Gas Engine Co., *Oakland, Cal.,* (mail) 972 62nd Street.

HENDRY, M. JAMES (A) sales engineer, Agni Motor Fuel Co., *Chicago,* (mail) 2022 Seminary Avenue.

HENRY, GUY P. (M) chief engineer, Studebaker Co., *Detroit,* (mail) 1412 Edison Avenue.

HITKE, KURT (M) superintendent, Kenworthy Motors Corporation, *Mishawaka, Ind.,* (mail) Box 198.

HOCKENBERGER, G. C. (M) engineer, 212 Union Avenue, *Bridgeport, Conn.*

HOWELL, HORACE L. (A) manager of research, National Railway Appliance Co., 50 East 42nd Street, *New York City.*

HULBERT, L. G. (J) metallurgist, Locomobile Co., 2 Main Street, *Bridgeport, Conn.*

HUPP, R. C. (M) consulting automotive engineer, 1260 Parkview Avenue, *Detroit.*

JACKSON, THOMAS (J) draftsman, Holt Mfg. Co., *Peoria, Ill.*, (mail) 509 Greenlawn Avenue.

JAMISON, ALEX. C. (A) Western representative, Sheldon Axle & Spring Co., Wilkes-Barre, Pa., (mail) 7416 Lake Park Avenue, *Chicago.*

JOHNSTONE, LLOYD GEORGE, JR. (A) general manager, Gilbert Motors Co., 10 High Street, *Boston.*

KEITH, EBEN S. S. (A) president, Keith Car & Mfg. Co, New York City, (mail) *Sagamore, Mass.*

KOCHER, EDWARD H. (M) manufacturing engineer, Bijur Motor Appliance Co., Hoboken, N. J., (mail) West Main Street, *Boonton, N. J.*

KOPPER, FREDERICK, JR. (M) mechanical engineer, Bureau of Standards, *Washington.*

LANE, RALPH F. (J) factory layout draftsman, Oakland Motor Car Co., *Pontiac, Mich.*, (mail) 23 Williams Street.

LANSING, RAYMOND P. (M) chief engineer, Bijur Motor Appliance Co., *Hoboken, N. J.*

LAVIER, T. H. (M) vice-president and chief engineer, Ray Battery Co., *Ypsilanti, Mich.*

LEE, STEPHEN M. (J) laboratory assistant, Bureau of Standards, *Washington.*

LEVENE, BENJAMIN (A) engineer, Levene Motor Co., Inc., 2200 Diamond Street, *Philadelphia.*

LEVINE, BERNARD (J) proprietor, Automotive Electrical Repair Shop, *New York City*, (mail) 279 Broome Street.

LOLLEY, WILLIAM H. (A) director of exports, Standard Parts Co., 11th and Walnut Streets, *Cleveland.*

LOUGH, HECTOR V. (M) consulting engineer, Hartford Rubber Works Co., *Hartford, Conn.*, (mail) 194 Washington Street.

MCCULLOUGH, R. C. (A) director of distribution, Dura Mechanical Hardware Co., Inc., *Toledo*, (mail) 522 West Delaware Avenue.

MCFARLAND, W. LEWIS (A) service engineer, 911 Independent Life Building, *Nashville, Tenn.*

MCMULLEN, V. E. (M) superintendent, engine division, Hercules Corporation, *Evansville, Ind.*, (mail) 422 Kentucky Avenue.

MOORE, WHITLEY B. (J) sales engineer, Timken Roller Bearing Co., Canton, Ohio, (mail) 450 Monadnock Building, *San Francisco.*

MOSS, J. W. S. (M) manufacturing engineer, Ever-Tyte piston ring division, Walter A. Zelnicker Supply Co., *St. Louis*, (mail) 5370 Pershing Avenue.

NEIGH, JOSEPH R. (A) director of service, Bessemer Motor Truck Co., *Grove City, Pa.*, (mail) 306 West Main Street.

NEIGHBOUR, L. B. (M) agricultural engineer, Marseilles works, Deere & Co., *East Moline, Ill.*

NIKONOW, J. P. (M) mechanical and electrical engineer and patent attorney, Room 413, 136 Liberty Street, *New York City.*

NILES, ALFRED S., JR. (M) aeronautical structural engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

NORDSTRUM, GEORGE W. (A) secretary and treasurer, Aetna Ball Bearing Mfg. Co., 213 Institute Place, *Chicago.*

MULLER, MICHAEL (A) engineer, automotive department, Vacuum Oil Co., *Chicago*, (mail) Apartment 3, 1050 Ardmore Avenue.

OPITZ, F. M. (M) president and manager, Perfex Radiator Co., *Racine, Wis.*

PHILLIPS, ANDREW EDWARD (A) chief engineer, Phillips Steamer Co., 9605 Silk Avenue, *Cleveland.*

PIERSON, LISLE A. (A) service manager, Mack Motor Truck Co., 59 Sanford Street, *Hartford, Conn.*

POWERS, HARRY H. (A) machine shop foreman, Remy electric division, General Motors Corporation, *Anderson, Ind.*, (mail) 207½ East 12th Street.

PRICE, JOHN C. (M) engineering representative, Jones & Lamson Machine Co., Springfield, Vt., (mail) Apartment 6, 823 Sheridan Road, *Chicago.*

REAM, FRED H. (M) engineering section, Shockezer division, National Steel Products Co., *Dayton, Ohio*, (mail) Lock Box 122.

REEVE, EDWARD (F M) superintendent, Wolseley Motors, Ltd., Adderley Park, *Birmingham, England.*

RIMBACH, RICHARD (J) metallurgist in charge of research laboratory, Standard Steel Car Co., *Butler, Pa.*, (mail) 223 West North Street.

ROBERTSON, CHARLES J. (A) mechanical engineer, Evans Stamping & Plating Co., *Taunton, Mass.*, (mail) 185 Highland Street.

ROBINSON, L. G. (A) sales manager, Bantam Ball Bearing Co., *Bantam, Conn.*

ROWAN, A. H. (J) service manager, Drexel Motors Co., *Houston, Tex.*, (mail) 2010 Crocker Street.

SATER, CHESTER WALL (A) supervisor of trucking, Great Atlantic & Pacific Tea Co., Jersey City, N. J., (mail) 71 Irving Place, *New York City.*

SCARR, FRANCIS J. (A) assistant to supervisor of motor equipment, Standard Oil Co. of New Jersey, Standard Oil Building, *Baltimore.*

SCHLUND, WILLIAM J. (A) service manager, Peerless Motor Car Co., *Cleveland.*

SCHUMANN, FRANK A. (M) master mechanic, Willys Corporation, *Elizabeth, N. J.*

SHAKESPEARE, MONROE (J) engineer, Shakespeare Co., *Kalamazoo, Mich.*, (mail) 601 Melrose Street.

SHARP, CLAYTON HALSEY (M) technical director, Electrical Testing Laboratories, 80th Street and East End Avenue, *New York City.*

SMITH, GEORGE AUSTIN, JR. (A) automotive sales department, Electric Storage Battery Co., 101 West End Avenue, *New York City.*

SMITH, HARRY G. (M) engineer, Holley Carburetor Co., *Detroit*, (mail) 1647 Fairview Avenue.

SMITH, LAWRENCE VICTOR (J) cadet engineer, Public Service Electric Co. of New Jersey, Newark, N. J., (mail) 2233 Parkwood Avenue, *Toledo, Ohio.*

SPRAY, JUDD W. (A) district manager of sales, Timken Roller Bearing Co., Canton, Ohio, (mail) 525 Book Building, *Detroit.*

STEESE, HEATON S. (J) salesman, A. Elliott Ranney Co., *New York City*, (mail) 161 East 79th Street.

SUDDUTH, ARTHUR L. (J) instructor, School of Automotive Electricity, *Milwaukee*, (mail) 3rd Apartment, 163 Mason Street.

SWEENEY, DANIEL M. (A) supervisor of distributors, United Motors Service, Inc., General Motors Building, *Detroit.*

THOMPSON, R. M. (A) wholesale salesman, Erwin Greer Automobile Co., *Chicago*, (mail) 4600 Champlain Avenue.

VICKERS, HARRY F. (J) engineer, Arthur L. Eaton, 3769 Moneta Avenue, *Los Angeles, Cal.*

WAGSTAFF, ALFRED, JR. (M) Room 3, 290 Lenox Avenue, *New York City.*

WALKLEY, F. H. (M) chief engineer, Dayton Steel Foundry Co., *Dayton, Ohio*, (mail) 431 Brightwood Avenue.

WARNOCK, T. E. (M) truck engineer, Paige-Detroit Motor Car Co., *Detroit*, (mail) 1392 Manistique Avenue.

WEBSTER, H. F. (M) factory manager, Denman-Myers Cord Tire Co., *Warren, Ohio.*

WEITZENKORN, JOSEPH W. (M) vice-president and general manager, Molybdenum Corporation of America, 1011 Empire Building, *Pittsburgh.*

WERNER, RALPH M. (A) chief engineer, Ralph M. Werner & Co., *Brooklyn, N. Y.*, (mail) 472 14th Street.

WEST, PHILIP E. (A) division head, technical department, General Motors Export Co., 120 West 42nd Street, *New York City.*

WESSELLS, WALTER B. (J) 315 Dolphin Street, *Baltimore.*

WHEELER, EDWIN S. (A) assistant manager, technical department, International Nickel Co., 67 Wall Street, *New York City.*

WOLFARD, MERL RUSKIN (M) engineer in charge of research laboratory, Hopewell Brothers, Watertown, Mass., (mail) 29 Everett Street, *Cambridge, Mass.*

WOLFE, CHASE W. (A) manager, pneumatic truck tire department, Cudahy, Wis., (mail) 734½ Wentworth Avenue, *Milwaukee.*

WOLFINGER, LOUIS F. (A) service engineer, Government Vocational Training, *Los Angeles*, (mail) Hotel Pleasonton, 1120 South Grand Avenue.

WRIGHT, J. C. (S M) chief industrial education service, Federal Board for Vocational Education, *Washington*, (mail) 200 New Jersey Avenue, Northwest.

WRIGHT, THOMAS C. (M) chief engineer, Standard Steel & Bearings, Inc., 5001 Lancaster Avenue, *Philadelphia.*

WRIGHT, WILLIAM E. (M) chief of engineering department, Twentieth Century Machinery Co., Milwaukee, (mail) 221 East Park Avenue, *Waukesha, Wis.*

Publications of Interest *to* S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

AN ANALYSIS OF THE REPORTS OF THE NEBRASKA TRACTOR TESTS. By E. A. White. Published by *Farm Implement News*, Masonic Temple, Chicago. 76 pages.

In this reprint there is given the official report of 65 tractor tests conducted at the University of Nebraska. The reports proper are preceded by an analysis of the results with graphs and tables illustrating fuel consumption, thermal efficiency, governor variation, and drawbar pull. One table is presented giving the volumetric, thermal, friction and belt efficiencies of all the tractors tested.

STRENGTH OF SCREW FASTENINGS IN PLYWOOD. Technical Note No. 149. Published by Forest Products Laboratory, Madison, Wis. 2 pages.

If the screw fastenings in plywood construction are to be as strong as the plywood itself, it is important to adapt the size of screw, spacing, and margin to the particular species and thickness of plywood used. Tests made at the Forest Products Laboratory have shown that the commonly-used plywood species may be divided into three groups, all woods in any one group requiring the same screw fastening to develop maximum strength. A table gives the recommended screw sizes, margin and spacing for use with each group and plywood thickness.

COMPARATIVE TESTS OF STEELS AT HIGH TEMPERATURES. By R. S. MacPherran. Paper read before the American Society for Testing Materials, 1315 Spruce Street, Philadelphia. 9 pages.

The tests recorded in this paper were made to determine the comparative properties of various steels at high temperatures with a view to obtaining information as to the best material for use under operating conditions of 600 to 1000 deg. fahr. These tests were made on carbon and alloy steels, both rolled and forged. While the tests would not warrant the drawing of any definite conclusions, they, at least, throw considerable light on the subject and indicate that further consideration should be given to the properties of various alloy and carbon steels at high temperatures.

CARE AND USE OF THE HYGROMETER IN KILN DRYING. Technical Note No. 148. Published by Forest Products Laboratories, Madison, Wis. 2 pages.

Several basic practices are suggested in this note for the proper handling and correct use of hygrometers in the interpretation and regulation of kiln conditions.

THERMAL EXPANSION OF COPPER AND SOME OF ITS IMPORTANT INDUSTRIAL ALLOYS. By Peter Hidnert. Scientific Paper No. 410 of the Bureau of Standards. Published by Superintendent of Documents, Government Printing Office, Washington. 159 pages.

Data on the thermal expansion of 128 samples of copper and its important alloys of various compositions, heat-treatments, mechnical treatments, etc., are presented. The specimens contained from 56 to 100 per cent of copper and were prepared in a number of ways; cast, cast and cold-rolled, extruded, extruded and cold worked, hot-rolled and cold worked. Most of the samples were examined from room temperature to about 300 deg. cent. (572 deg. fahr.). Practically all the available information on the thermal expansion of copper and its alloys is briefly reviewed. Definite mathematical relations were found to exist between the coefficients of expansion and the copper content of most of the alloys investigated. In general, the coefficient of expansion increases with a decrease in the copper content. The addition of lead or tin has a decided effect on the coefficient; the former element generally decreases and the latter increases the coefficient. The appendix gives average coefficients of expansion of all the samples investigated.

REMOVAL OF GLUE STAINS. Technical Note No. 146. Published by Forest Products Laboratory, Madison, Wis. 1 page.

Casein and vegetable glues containing caustic soda produce stains on certain kinds of wood, notably the oaks, maple, cherry, elm, ash, birch and beech. The staining is due to the action of the alkali in the glue on the constituents of the wood forming a substance related to ink. No means have yet been found of preventing this chemical action but this note describes precautions which can be taken to keep the discoloration from the finished surfaces.

SOME FACTORS OF AIRPLANE ENGINE PERFORMANCE. By Victor R. Gage. National Advisory Committee for Aeronautics Report No. 108. Published by the National Advisory Committee for Aeronautics, Washington 29 pages.

This report contains the results of a search for fundamental relations between many variables of engine operation. The data used came from over 100 groups of tests made upon the Liberty 12-cylinder and three models of the Hispano-Suiza engine in an altitude chamber, where conditions simulated altitudes up to about 30,000 ft.; with engine speeds ranging from 1200 to 2200 r.p.m. and compression ratios ranging from under 5 to 1 to over 8 to 1. The data taken on the tests were exceptionally complete, including variations of pressure and temperature, besides the brake and friction torques, rates of fuel and air consumption, the jacket and exhaust heat losses. It was found that the friction torque increases approximately as a linear function of engine speed at a given air density and that the friction horsepower increases approximately as the square of the speed. The data indicated that the pumping losses are about half of the total friction. For a given process of combustion and at a constant speed the engine power proved to be directly proportional to the weight of the charge supplied; in other words, proportional to the charge density at the beginning of compression. The volumetric efficiency increases with an increase of the air temperature at a constant pressure, so that power does not decrease as fast as the air density when the temperature is raised, due to changes in vaporization and heat transfer.

SOME MECHANICAL PROPERTIES OF HOT-ROLLED MONEL METAL. By P. D. Merica, R. G. Waltenberg and A. S. McCabe. Paper read before the American Society for Testing Materials, 1315 Spruce Street, Philadelphia. 2 pages.

Mean values of the tensile properties of hot-rolled or hammered monel metal rods are computed from the results of 500 tensile tests. The average proportional limit of hot-rolled monel metal varies from 35,000 to 49,000 lb. per sq. in., and is approximately 80 per cent of the yield-point. It possesses a remarkable degree of toughness as compared with other metallic materials, including alloy steels. The average proportional limit in torsion, or shear, varies from 20,000 to 29,000 lb. per sq. in., or from 55 to 67 per cent of that in tension. This metal will withstand approximately 75,000,000 alternations of tension and compression at a maximum fiber stress of 38,000 lb. per sq. in. and approximately 2,000,000 alternations at 43,000 lb. per sq. in. The alternating stress tests were carried out at the Bureau of Standards by Mr. Waltenberg; the other tests were made at the research department of the International Nickel Co.